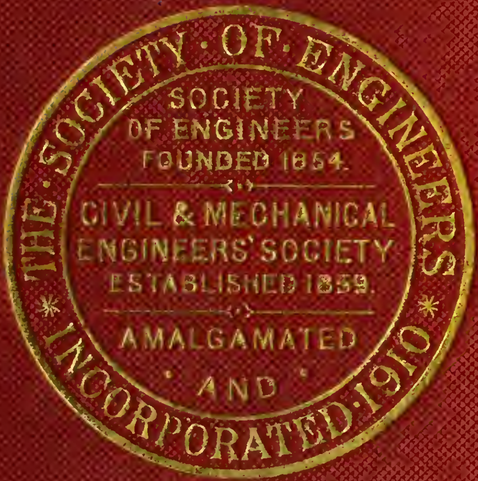


THE · SOCIETY · OF · ENGINEERS

SOCIETY
OF ENGINEERS
FOUNDED 1854.

CIVIL & MECHANICAL
ENGINEERS' SOCIETY
ESTABLISHED 1859.

AMALGAMATED
· AND ·

* INCORPORATED · 1910 *

SecT i 022
20
S A

Presented to
The Library
of the
University of Toronto
by
THE ENGINEERING INSTITUTE
OF CANADA.

20
A

LIBRARY

CANADIAN SOCIETY
— LIBRARY —
CIVIL ENGINEERS

Digitized by the Internet Archive
in 2011 with funding from
University of Toronto

http://www.archive.org/details/journalsoe1916soci

Percy Griffith, M.Inst.C.E., F.G.S , F.R.San.I.,
President of The Society of Engineers (Incorporated) for the year 1916.

(See page 5.)

(THE)

SOCIETY OF ENGINEERS

(INCORPORATED).

SOCIETY OF ENGINEERS: ESTABLISHED MAY, 1854
CIVIL & MECHANICAL ENGINEERS' SOCIETY: FOUNDED MAY, 1859 } AMALGAMATED AND INCORPORATED 1910

Journal and

TRANSACTIONS FOR 1916.

EDITED BY

A. S. E. ACKERMANN, B.Sc.(ENGINEERING).
A.C.G.I., A.M.Inst.C.E., M.R.S.I.,
SECRETARY.

(All rights of Publication and Translation are Reserved.)

LONDON
PUBLISHED BY THE SOCIETY OF ENGINEERS
(INCORPORATED).
17, VICTORIA STREET, WESTMINSTER, S.W.
1916.

620.6
S711

TH
1
S67
1916

LIBRARY
APR 3 19[illegible]2
UNIVERSITY OF TORONTO

789684

THE SOCIETY OF ENGINEERS

(*INCORPORATED*).

SOCIETY OF ENGINEERS: ESTABLISHED MAY, 1854
CIVIL & MECHANICAL ENGINEERS' SOCIETY: FOUNDED MAY, 1859
AMALGAMATED AND INCORPORATED 1910.

COUNCIL AND OFFICERS FOR 1916.

Council.

President—PERCY GRIFFITH.

Vice-Presidents
- HENRY CHARLES ADAMS.
- WILLIAM BEEDIE ESSON.
- WALTER NOBLE TWELVETREES.

HENRY ADAMS.
CHARLES TROUBRIDGE WALROND.
BERTRAM HENRY MAJENDIE HEWETT.
FRANK HARVEY HUMMEL.
GEORGE ARTHUR BECKS.
FREDERICK LEONARD BALL.
GERALD OTLEY CASE.
BURNARD GEEN.
TONY JULES GUERITTE.
THE RT. HON. LORD HEADLEY.

Associate Member of Council—CHARLES EDWIN MAY.

Members of Council, ex-officio.

Past Presidents
- (1915) NORMAN SCORGIE.
- (1914) HENRY CHAWNER HINE SHENTON.
- (1913) ARTHUR VALON.
- (1912) JOHN KENNEDY.

Hon. Secretary and Hon. Treasurer—DAVID BUTLER BUTLER.

Trustees
- SIR DOUGLAS FOX.
- SIR ALEXANDER BLACKIE WILLIAM KENNEDY, LL.D., F.R.S.
- ALEXANDER SIEMENS.

Hon. Solicitors—MESSRS. BLYTH, DUTTON, HARTLEY & BLYTH.
MR. R. H. WILLCOCKS, B.A., LL.B.

Bankers—LLOYDS BANK (LIMITED).

Auditors—MESSRS. BEGBIE, ROBINSON & COX.

Secretary—A. S. E. ACKERMANN, B.Sc.(ENGINEERING).

OFFICES:
17, VICTORIA STREET, WESTMINSTER, S.W.
Hours, 10 *a.m. to* 4 *p.m.; Saturdays*, 10 *a.m. to* 1 *p.m.*
TELEPHONE: VICTORIA 244.
TEL. ADDRESS: "WINDOLITE, VIC. LONDON."

PLACE OF MEETING.

CAXTON HALL, WESTMINSTER, S.W.

*The Society is not responsible either for the statements made
or for the opinions expressed in the papers or
in the discussions thereon.*

All rights of publication and translation are reserved.

PERCY GRIFFITH,

President of the Society for the year 1916.

Son of the late W. P. Griffith, Government Printer, London, our new President was born in 1865. He was educated privately: passed all three classes of the College of Preceptors: and the Cambridge Local Examination in honours; matriculated in the Engineering Department of King's College, London; was a student at the Crystal Palace School of Engineering, and was articled to H. Young & Company, Eccleston Iron Works, Pimlico, with whom he afterwards remained for two years as an assistant, having charge, amongst other works, of a new pumping station for Godalming Water Works. In 1888 he became Assistant to the late Jabez Church, M.Inst.C.E., whom he joined in partnership in 1892.

Since Mr. Church's death in 1896 he has practised alone as a consulting gas and water works engineer in Westminster, and has designed and carried out a large number of gas and water works in various parts of the country, including the largest water works borings in England (at Lincoln and Gainsborough), and extensions of the water works at Gainsborough, Braintree, Broadstairs, Chelmsford, and elsewhere. He carried out the new Gas Works at Cromer, the new water works at Skegness and Selby, and advised the Urban District Councils of Llandrindod Wells, Blaenavon, Wirksworth, East Cowes, West Cowes, Hornsea, Portland, and many other public bodies and private clients; and has been engaged in the preparation of plans and giving evidence in connection with Bills before Parliament; is advising the Howden Rural District Council on a water scheme estimated to cost £60,000 (temporarily suspended on account of the War), and also the Rt. Hon. Viscount Peel on the water supply of East Meon, Hants. He is a Member of the Institution of Civil Engineers, a Fellow of the Royal Sanitary Institute, a Member of the Institutions of Mechanical Engineers, and Gas Engineers, and of the Southern District Association of Gas Managers, a Past President of the old Society of Engineers, Secretary of the Institution of Water Engineers, and a prominent Freemason.

LIFE GUARDS FOR MOTOR VEHICLES.

By H. Conradi (Associate Member.)

The number of fatal and serious street accidents in London, which was steadily growing year by year before the war, has been noticeably increased since the reduction in street illumination has been enforced, and the present is therefore an appropriate time to consider how at least a part of these casualties might be avoided. Evidently there is no simple and undeniably effective means of preventing all street accidents, even if it were possible to re-establish the degree of street illumination belonging to the pre-war period and at the same time to enforce uniformly heavy penalties on reckless drivers (the heedless pedestrian usually pays a penalty far more severe than statute law would provide). The problem involves varying and to some extent uncontrollable factors, such as the width of roadway relative to the quantity of traffic carried, the mixture of slow and fast-moving vehicles of diverse types, the condition of the road surface, and the temperamental and physical peculiarities of individuals.

From evidence laid before the Select Committee of the House of Commons on London Street Traffic (1913), and from other returns (see Appendix page 17), the opinion, on which this paper is based, has been formed, that the motor omnibus has, on the whole, been responsible for more deaths than any other class of road vehicle, and the number of deaths and injuries increases year by year, although the accidents per omnibus and per mile of route have been reduced in number. It clearly appears from these facts that an efficient life guard for use on motor vehicles is a necessity, and hence the present notes, describing some types of apparatus that have been designed for attachment to motor vehicles with the purpose of preventing serious injuries to persons accidentally run into by such vehicles.

The essentials of a life guard of this kind are (i.) that it should effectually prevent the wheels of the car from passing over the body or limbs of a person lying in the roadway. (ii.) that it should do this with the minimum of shock and injury to the person struck and (iii.) that its cost should be low enoug to make it commercially usable on an extensive scale. The following descriptions have been abstracted and the accompanying illustrations reproduced from Patent Office Specifications, by kind permission of the Controller of H.M. Stationery Office.

Gibb's patent (No. 2514 of 1902) proposed an apparatus consisting of a basket, the projecting end of which is cushioned to lessen the possibility of injury to persons coming forcibly in contact with it. The basket is suspended above the ground, but when struck, it drops into an inclined position on to rollers, thus tending to pick up the fallen person.

Bennett's patent (No. 27670/1906) is somewhat similar in principle, a pivoted frame carrying a net or a series of bars being fixed on the front of the omnibus, and so arranged that its front edge is a few inches above the surface of the road. When an obstacle strikes this frame its front edge is depressed and tends to pick up and carry the object thus encountered. Provision is made by means of springs for lessening the shock due to collision with the obstacle.

MacFerran's patent (No. 25441/1907) involves a framework covered with netting, suspended under the vehicle. When the frame encounters an obstacle the front part of it is disengaged from its supports and falls to the ground, thus tending to pick up the fallen object.

Patent No. 20957 of 1909, consists fundamentally in a hinged cradle projecting slightly in front of the leading wheels of the car, but the cradle is held up by adjustable balance weights. The effect of meeting an obstruction is that the front edge of the cradle is lowered and tends to pick up the object with which it collides. If the balance weights are not used the cradle can be lowered by releasing a catch actuated from the driver's seat.

A much more elaborate apparatus is Say's patent (No. 1801 of 1913) which includes cradles projecting in front of both the steering and rear wheels of the car, each cradle having two arms attached to the axle, and being released by mechanism, actuated by telescopic feeler bars, placed in front of the vehicle and also in advance of the rear wheels. When the feeler bar strikes an obstacle the cradles are automatically let fall and prevent the obstruction from being run over by the wheels, while at the same time the engine is cut off and two brakes are brought into action on the rear wheels. The front cradle is so constructed that it effectually guards the front wheels even when they are at an angle with the body of the vehicle. The author is not aware to what extent this apparatus has been tested in actual use, but the design seems to fulfil the requirements for this class of apparatus, except that possibly the cost of applying it to existing vehicles might be prohibitive.

A design (No. 23599/1908), that differs considerably from those already mentioned, consists of a pair of open jaws placed in a horizontal plane, beneath the front of the vehicle. When released, the jaws are projected forward and closed, and at the same time nets placed at the sides of the jaws are expanded, and it is claimed that a person seized by the jaws will also be thrown into the nets.

A wheel-guard that has been used on some of the motor omnibuses of the London General Omnibus Company is described in Howard's patent (No. 11741/1914) and is illustrated in figs. 1-4.

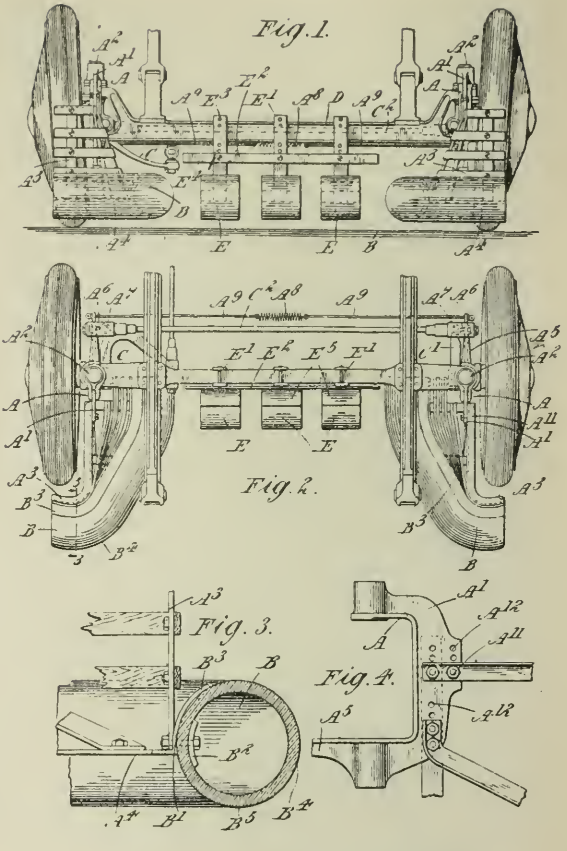
The following description is abstracted from the Patent Specification.

"A common fault with devices of this kind, such as have hitherto been proposed, has been the tendency to pin an obstacle of small height (such for example as an arm or hand) to the ground thus involving a person in injury to a limb even if the body of the person be protected. According to the present invention a wheel guard for a vehicle is provided with a deformable impact-receiving cushion adapted to expand in a downward direction upon impact with an obstacle for the purpose described. Preferably the cushion is provided at its lower portion with a covering of india-rubber or like material adopted to give high frictional effect with an obstacle. The cushion conveniently takes the form of a tube-like structure of canvas and india-rubber, the principal axis of the tube being disposed transversely to the line of advance to the wheel. According to one method of carrying the present invention into effect a steel shield is provided for each front wheel of the vehicle and is so supported from the framework of the vehicle as to turn with any steering movement of the wheel, so as constantly to be maintained in the necessary position in advance of the wheel. In operation, full impact with the cushion causes it to distend downwards and so obviate or reduce the risk of a portion of the obstacle, for example, the hand of a person or part of person's clothing, passing beneath the cushion. In the case, however, of what is first encountered being of small height, such for example as a person's hand, the friction between the rubber and the hand will serve to brush or sweep the hand along over the ground until fuller impact occurs with the person, which fuller impact is taken by the body of the cushion and results in the person being carried bodily along, free from serious injury."

The inventor's assumption that a person knocked down by a motor 'bus might have a hand or other member swept along the ground by the apparatus is not re-assuring, but it may be supposed that it is the lesser of two evils, and preferable to having one's body crushed beneath the wheels. It is possible also that other inventions of this nature have the same defect, but that the inventors do not admit it so frankly.

This invention includes modifications applicable to the rear wheels of a motor 'bus, and also a guard to be fixed between the front and rear wheels.

Fig. 1 is a front elevation and fig. 2 a plan of one method of carrying out this invention. Fig. 3 is a detail section on line 3-3 of fig. 2, and fig. 4 is a detail showing the attachment of the wheel guards to the frame.



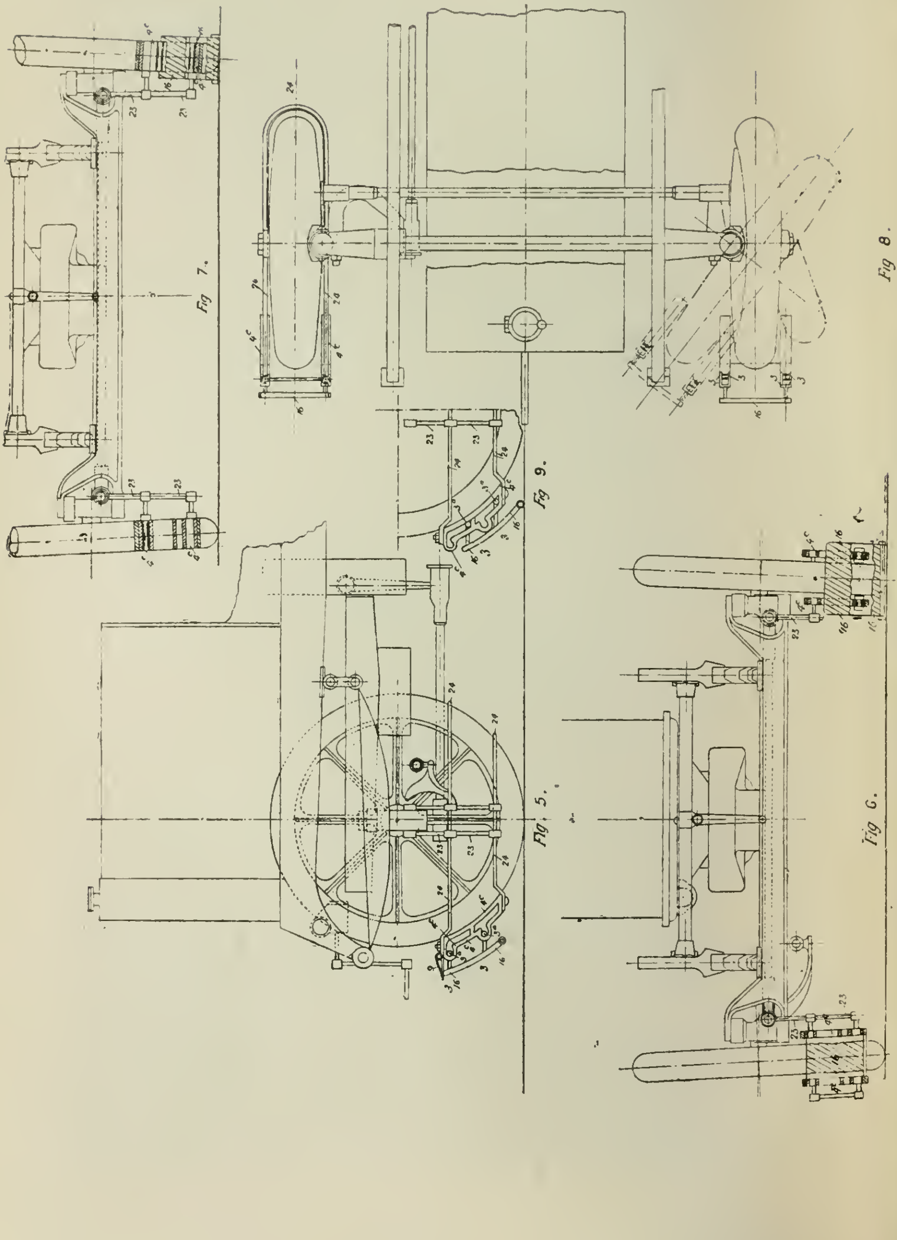
Figs. 1-4.—Howard's Life Guard.

The wheel-guard shown in figs. 1 to 4, comprises a G shaped supporting bracket A, having an external stiffening rib A^1, to which a vertical wood and steel framework or shield A^3 is bolted, extending inside and outside in front of the wheel, The lower edge A^4 of the shield A^3 is set close to the ground and carries an impact-receiving cushion B, formed of sections of rubber and canvas hose. In order that the shields A^3 may turn upon their pivots A^2 with the steering movements of the wheels, the brackets A have rearward extensions A^5 which carry studs A^6 engaged by lugs A^7 on the steering-mechanism of the front wheels. The lugs A^7 are mounted on the levers C and C^1. The back levers A^5 are held against the lugs A^7, by the spring A^8 in connection with the rods A^9. As shown in fig. 3, the stout impact-receiving cushion B, formed of sections of rubber and canvas hose is secured to the shield between a backing plate B^1, and a clamping plate B^2. The underface B^5 (fig. 3.) of the cushion, curves downwards towards the road, so that it leans in that direction when the face B_4 strikes an obstacle. Between the wheels another guard is connected to the axle D, as shown in fig. 1., of the chassis of the vehicle. This consists of several short sections E of rubber and canvas hose, each mounted on a vertical supporting bar E^1 bolted to the rigid axle D of the wheels ; which bars E^1 are also connected together by the horizontal bar E^2. Each of the cushions E is provded with a constraining plate E^5.

The Author's patent No. 22788/1912 is for a lifeguard made in four sections which can be used all together or separately, or in various combinations according to the circumstances. The first section prevents objects approaching the front wheels, the front of the chassis and the projecting car springs, and also forms an apparatus for raising an obstruction in its path. The second section guards the rear wheels but does not interfere with their freedom of motion ; the third section prevents approach to the sides of the chassis and the fourth section is a guard for the front of the radiator. All these sections can be quickly removed when necessary to effect repairs, etc. Provision is also made to prevent the hand, arm, or leg of a fallen person from passing under the guard and being crushed by the wheels of the vehicle. Another important feature of the invention is that it is designed to prevent serious injury from shock due to the impact of the vehicle with a person who is struck by it. This apparatus was, however, open to objection on the ground of cost.

Further investigation, aided by the opinions of makers of motor vehicles, led to the conclusion that the lateral space between the wheels may be considered comparatively safe, the danger zone being in the direct path of the wheels. The question of cost being also vital to the commercial possibilities of an apparatus of this kind, the author designed the life guard shown in figs. 5-11 (Patent No. 6299/1914).

It is composed of one or several curved links 4c, forming one or several cavities or grooves to serve as seats for a shaft or shafts or rollers 3a to rest in. Otherwise these links are similar to those used in the link motion of ordinary steam road and traction engines. These stationary links 4c are fixed to arms 24, bent round the wheel, giving further protection against side approach to it, and carried by arms 23 connected to the swivel arrangement of the steering gear, but so that the links are kept at the required distance from the ground and the wheel. In front and at some distance from the link 4c the protecting shield



FIGS. 5-9.—CONRADI'S LIFE GUARD.

16 of elastic material as india-rubber, leather, strong canvas, or tarpaulin forming part of the lifeguard is connected by means of fork-shaped arms 3, fixed to this shield, as indicated in plan, fig 8. Into these forks moveable rollers or shafts 3a are inserted (figs. 5 and 9), which are made to slide down the inner surface of the link, carrying the shield with them. In case of an accident the body striking on the shield 16, in front of the wheels, pushes it, and consequently the rollers or shafts, out of their seats and causes them to slide instantly down the inner surface of the links, thus dropping the shields, which slide upon the ground assisted by the roller at the bottom. The approach of the fallen person to the danger zone of the wheel is therefore effectively prevented. The action of the shield is automatic.

Fig. 5 is a side elevation, and Fig. 6 a front elevation showing the position of the links 4c, one on each side of the wheels, for the large wheels of omnibuses or heavy trade and traction engines and lorries. Fig. 7 is a front elevation indicating on the right hand side in section, the shield dropped on to the ground and on the left hand side the section of the link 4c. Only one is used for small wheels. Fig. 8 shows in plan, on the right hand side, the position of the links and shield, with the arms 24 fixing them to the swivel arrangement of the steering gear box, while on the left-hand side the wheel, with the links and shield, is shown turned at an angle. Fig. 9 is part of the side elevation indicating the position of the link 4c fixed by the arms 23 and 24, with the shield 16 dropped on to the ground, the rollers or shafts 3a resting on the lower ends of the links.

The proposal that the shield should be dropped (in anticipation of an accident) and raised when necessary by means of levers near the driver's seat, introduces a complication of levers which is undesirable in practice, and it is, therefore, preferable for the shield to drop automatically by contact with an obstacle and to be raised afterwards by hand. An objection has also been made that the shield, in falling, might injure a limb of a person lying on the ground, but this difficulty has been overcome by making the shield in two parts, the upper portion being fixed; the moving lower portion being, therefore, lighter and not capable of dealing a heavy blow. Figs. 10 and 11 show this modified construction of the links 4c and the shield 16. Here the upper part of shield is pressed back so as to form a buffer when an obstacle is encountered, but the lower rollers and the lower part of the shield are arranged to fall down when struck so as to prevent approach to the wheel. The lower edge of the shield is in the form of a squeegee having a certain amount of resilience, and openings are provided in the shield to allow the passage of dust and mud from the wheels. This guard may be applied to both the front and rear wheels. A company was in course

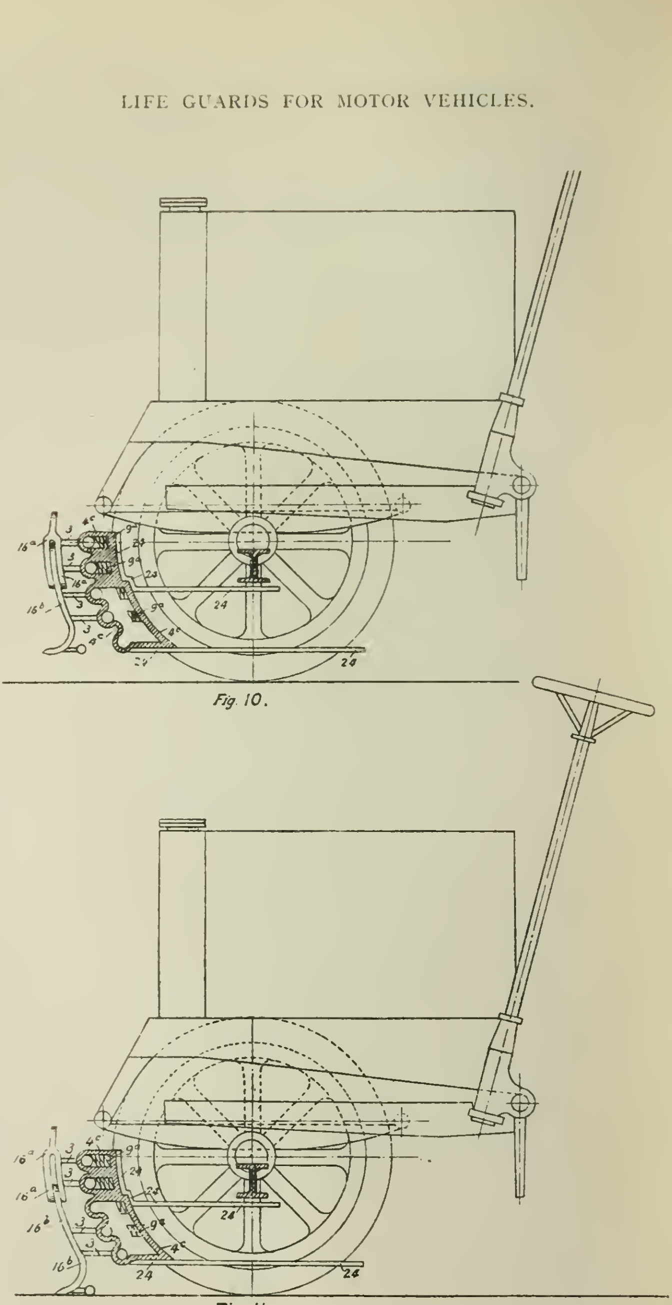


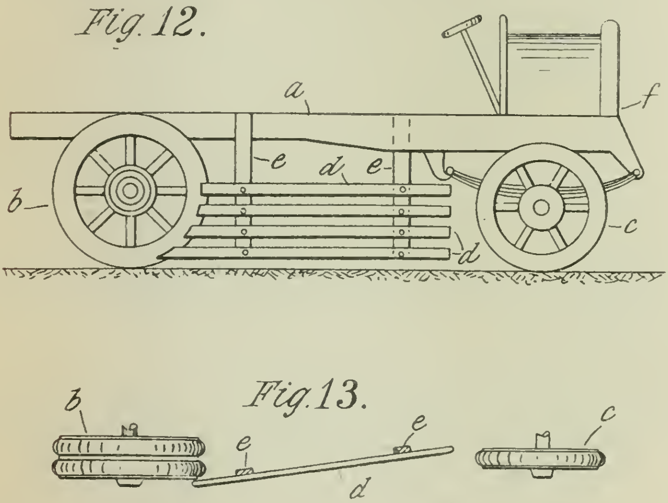
Fig. 10.

Fig. 11

Figs. 10-11.—Conradi's Life Guard—Modification of Wheel Shield.

of formation to place this invention on the market, when the outbreak of war put an end to the project for a time.

A side-guard which is used on many of the London omnibuses is Hawksworth's Patent, No. 24757/1912, and serves to protect persons from falling beneath the rear wheels (Figs. 12-13). It consists of a frame carried at each side of the vehicle so that with only a slight inclination its rear end overlaps the outside of the rear-wheels, and thus serves to push anyone coming in contact with it clear of the rear wheels. The battens of the frame are preferably made of wood, and can thus easily be repaired or renewed. Fig. 12 is a side view, and Fig. 13 is part of the plan, showing the flat frame inclined, instead of being parallel to the side of the omnibus. *a* represents the frame or chassis of an omnibus or other motor-vehicle, *b* indicates the rear-wheels and *c* the front-wheels, *dd* are the bars forming the rear wheel-guard or fender, carried by vertical rods *e* secured to any convenient part of the underframe *a*. The bars may be curved or bent in plan and the lowest bar may advantageously be about 3 to 4 inches above the ground. The rods *e* may also be combined with spring devices or be made in two parts connected by a telescopic or sliding spring-joint, so that, if the bottom of the frame should strike the ground, owing to the jolting of the vehicle, it would yield sufficiently to prevent damage. Rollers may be fitted at the bottom of the frame to enable it to ride more easily over obstructions.



Figs. 12-13.—Hawksworth's Life Guard.

Reviewing, generally, the various types of life-guard herein described, the author concludes that apparatus of this kind is effective only when it absolutely prevents any part of the body of a fallen person from being run over by the front and rear wheels of the vehicle, and that apparatus fixed several inches above the road surface and incapable of being automatically and instantaneously dropped in case of accident is not in itself a sufficient safeguard against serious injury to persons knocked down by a motor-bus or similar vehicle.

There are, of course, accidents due to motor vehicles against which the apparatus referred to in these notes is no protection, as for instance those due to collisions, entering or leaving a car in motion, etc. ; but the great majority of street accidents are those in which persons are knocked down, and fatally or seriously injured by wheels passing over their bodies or limbs, and such accidents are more frequent now than at any previous time : hence the urgent necessity arises for the consideration of how the fatality of this kind of accident may be appreciably reduced. The author is strongly of opinion that motor vehicles, like tramcars, should be obliged by law to carry life-saving devices, and he hopes that these few notes will serve to stimulate interest in the matter, and will be gratified if the paper evokes constructive criticism on the design of apparatus for minimizing the danger to life which is such a deplorable feature of London street traffic at the present time.*

---

* *The Editor will be glad to receive for publication suitable written communications on the subject of Mr. Conradi's paper.*

Appendix I.

Extracts from evidence given before the Select Committee of the House of Commons on London Street Traffic, appointed in 1912 " to inquire into the circumstances that have led to the large and increasing number of fatal accidents in the Metropolis, due to Motor Omnibuses, and other forms of power-driven vehicles, and to make recommendations as to the measures to be taken to secure greater safety in the streets."

From the evidence of Sir W. Nott-Bower, Commissioner of Police for the City of London, 7th January, 1913.

(i.) Number of mechanically propelled vehicles entering the City between 7 a.m. and 7. p.m. on April 28th, 1911, was 19,002, of which 5,686 were motor omnibuses. The corresponding number of horse-drawn vehicles was 53,094.

(ii.) Number of vehicles passing certain points in the City between 8 a.m. and 8 p.m., on 26th November, 1911, was :—

Mansion House	30,934
Blackfriars Bridge	30,191
Ludgate Circus	27,949
King William Street	24,344
Mansion House Station	24,131

(iii.) " If any invention for a 'man-catcher' could be brought to perfection, so as to enable regulations to be made on the subject, that course would be followed at once. The difficulty at present was that there was no suitable invention."

From the evidence of Dr. Waldo, the City Coroner, 14th January, 1913 :—

" With regard to apparatus for preventing or miminizing accidents, he had often spoken to juries of the advantage of life-guards or fenders. Such things were fastened to the front of tramcars, but did not seem applicable to motor vehicles. It should not however, be beyond human ingenuity to make them applicable, especially as they would be of inestimable value in reducing the dangers of the streets. Children would probably benefit more than anybody else."

From the evidence of Mr. Kellaway, a Member of the Commission, 16th January, 1913.

" In 1907, 1,200 buses killed 35 people = 1 death per 34 busses.
,, 1912, 2,400 ,, 138 ,, = 1 ,, 17 ,,

Each vehicle has therefore become twice as deadly."

From the evidence of Superintendent Bassom, Chief of Hackney Carriage Department of Scotland Yard, 30th January, 1913.

" Notwithstanding the improvements that had been effected in motor 'buses, the fatal accidents in connection with them were increasing. He did not think it was beyond human ingenuity to devise a safety guard for motor vehicles. . . . . He thought improvements would be made so that in the near future there would be some life saving device which would minimize street accidents. If any really suitable device were brought forward, the Commissioner of Police would, he thought, recommend the issue of an order to make its adoption compulsory."

From the evidence of Mr. W. H. Kendall, Chief Clerk to the Commissioner of Police, 22nd April, 1913.

" The number of persons returned as injured in the streets in 1901 was 9,197, and in 1911 was 18,749, an increase of 104 per cent. in ten years."

From the evidence of Mr. A. H. Stanley, Managing Director of the London General Omnibus Company, 29th May, 1913.

" For a considerable time extensive experiments had been carried on with a view to finding some effective lifeguard for the front and rear wheels. They were now fitting a number of omnibuses with guards for the purpose of preventing pedestrians from getting under the rear wheels, but so far they had not been successful in finding a suitable apparatus for the front wheels. They would be very glad to pay a substantial sum to anyone who would provide them with an effective guard. . . . . Of a thousand consecutive non-fatal accidents which occurred in 1912, involving 1,066 persons, 693 were caused in connection with boarding and alighting from motor buses. These accounted for 65 per cent. of the total number, as against 6 per cent. of similar accidents which were fatal. In 199 cases, or 18 per cent. of the whole number injuries were caused by collisions, whereas the fatal accidents from this cause were only about 2½ per cent. of the total."

Appendix II.

Statistics of London Traffic from Various Sources.

From *The Daily Mail*, of 21st January, 1916.

" The total number of street fatalities caused by vehicles in the metropolitan area and City of London during 1915 was 867, as compared with 625 and 658 in 1913 and 1914 respectively, an increase on 1914 of nearly 32 per cent.

Mr. Herbert Samuel yesterday gave the following analysis :—

Private Motor-cars	191
Trade Vans (Horse)	162
Motor-omnibuses	156
Trade Motor-vans	150
Tramway-cars	87
Taxicabs	66
Motor-cycles	28
Bicycles	13
Broughams	9
Horses	4
Horse Cab	1
Total	867

Extract from 9th Annual Traffic Census, by H. Hewitt Griffin, F.R.S.S., M.J.I., published by *Motor Traction*, May 26th, 1915 :—

Fleet Street. (8 a.m. to 8 p.m.)

	Census taken April 23rd.		
	1915	1914*	1907
Number of Motor 'buses	2,744	3,551	995
,, Horse ,,	*nil.*	*nil.*	2,241
Motor 'bus per cent. of all 'buses	100	100	30·75
All vehicles	10,384	11,540	9,972
Per cent. of Power :—			
Mechanical	48·83	48·17	11·29
Horse	34·52	33·68	73·72
Human	16·65	18·15	14·99
	100	100	100

From *The Times*, of 15th August, 1913.

	1904.	1912.
Fatal accidents in the Metropolitan Police area	155	537
Non-fatal ,, ,, ,,	10,384	20,166

---

*The 1914 figures are given here because the 1915 census showed a diminution of 807 'buses passing along Fleet Street in 12 hours. All previous years having shewn an increase. The drop is accounted for by the number of 'buses at present " Somewhere in France." It will be seen that in 1914 the average number of motor 'buses passing was one every 16 seconds, and that practically one of every two vehicles passing was mechanically driven. The carefully tabulated returns from which the above figures have been taken, and also those relating to the annual census of traffic at Edgware Road and Putney Bridge are published in great detail in *Motor Traction*, and will repay careful study by all who are interested in London traffic. (See *Motor Traction* of 26/5/15, 21/7/15 and 3/11/15.)

"This means that, on every day of 1912, 55 persons were injured and that every 2 days 3 lives were lost. 141 of these fatal accidents occurred in very congested traffic and of these 82 or 58% were due to motor omnibuses, the next most fatal vehicle in the same conditions of traffic being the motor cab. . .

"In 117 miles of streets which are both tramway and motor 'bus routes, the following statistics were obtained :—

	1910	1911	1912
Fatal accidents caused by power--driven vehicles	67	107	126
Of the foregoing :—			
Fatal accidents caused by tramcars were,..	19	18	21
,, ,, ,, motor 'buses ,,	26	46	67

"The number of fatal accidents caused by motor 'buses, in the Metropolitan and City Police Areas in 1912, with 2,908 vehicles licensed, were 182, or 62·6 per 1,000 omnibuses. In the same year fatal accidents caused by power-driven vehicles within the County of London numbered 278, of which the motor omnibus was responsible for 141, or more than half, while there were only 3,000 motor omnibuses on the streets as compared with 11,000 other licensed public carriages and about 14,000 private power vehicles.

From *The Morning Post*, of 10th January, 1914 :—

"In the last three years the motor 'bus has on the whole been responsible for more deaths than any other class of vehicle, and the number of both deaths and injuries has increased each year. That the increase has been less in proportion both to the number of omnibuses put on the streets and to the yearly route and car mileage is satisfactory in a way, but even so the death rate is still deplorably high."

7th February, 1916.

MR. NORMAN SCORGIE, M.INST.C.E., PAST PRESIDENT, IN THE CHAIR.

PRESENTATION OF PREMIUMS.

THE Chairman presented the Premiums awarded by the Council for papers contributed during 1915, as follows :—

The Presidents' Gold Medal to Mr. Arthur H. Barker, Wh.Sc., B.A., B.Sc., for his paper on "Future Developments in Heating and Ventilation."

The Bessemer Prize, value £5 5s., to Mr. Alphonse Steiger, M.Inst.C.E., for his paper on "The Modern Development of Water Power."

A Society's Premium value £3 3s. to Mr. Sydney G. Turner, Barrister-at-Law, A.M.Inst.C.E., for his paper on "Law and Engineering—some points of contact."

A Society's Premium value £2 2s., to Mr. Frank Grove for his paper on "Main Roads; Past and Present."

Certificates were also presented by the Chairman to those who received premiums.

Mr. Scorgie further expressed the thanks of the Society to the authors of papers for which premiums had not been awarded, viz.: Captain R. W. A. Brewer and Messrs. A. S. E. Ackermann, Percy Griffith, L. S. Spiro, and A. E. Whitcher.

INDUCTION OF THE PRESIDENT.

Mr. Scorgie said that he had come to the end of his year of office and had now formally to introduce the President for the ensuing year, Mr. Percy Griffith, who was well known to many of the members. He had much pleasure in doing so, and in placing upon him the badge of office and handing to him the certificate of election. He felt sure that if Mr. Griffith's year of office was as pleasant as his own had been, he would be very sorry to leave the Chair.

Mr. Percy Griffith, having been invested with the badge of office, then took the Chair.

The **President** said that Mr. Norman Scorgie was not more sorry to leave the Chair than the members were to lose him as Chairman. He (the President) had a pleasant duty to perform although it was tinctured with disappointment and that was to thank him in the name of the Society. That which he had to say about Mr. Scorgie needed no further proof than that gentleman had given during his year of office as President. The position of President of that Society might appear to many to be a very simple one, but he could assure the meeting that it was not so. In the conduct of any Society of that sort, there were difficulties which had to be experienced before they could be understood, and by none could they be better appreciated than by members of the Council. Mr. Scorgie's work, both on the Council and as President had been most efficient. The meetings of the Council always threw a greater strain upon the Chairman, than the General Meetings did, and in Council meetings they had learned to appreciate the ability of the retiring President. Mr. Scorgie had proved himself a past master in the art. Associated professionally with municipal engineering, of which branch of the profession he was a distinguished ornament, the President had not had much scope for displaying professional ability when discharging his duties at their meetings, but in conducting the Society's affairs Mr. Scorgie had proved himself to be excellently equipped for the office he had filled so successfully during the past year. He had conducted the meetings with firmness and yet with the courtesy which was equally necessary, and in every respect he had won the admiration of all who had been in contact with him during his year of office. Those who had seen him presiding at general meetings knew his excellent gifts and, therefore, he (the speaker) need not say anything about them, in fact, he need have said very little to commend the vote to their attention ; he, therefore, proposed " That a hearty vote of thanks be accorded to Mr. Norman Scorgie for his services to the Society as President during the past year."

Mr. H. C. H. Shenton said that he had the very greatest pleasure in seconding the vote of thanks. Mr. Scorgie had been President during a year when his duties had been much less pleasant than they would have been in other years. There had been none of the ordinary occasions, as distinguished from meetings, upon which members could meet together to enjoy themselves. It had been the greatest advantage to the Society to have such a President during such a dismal period as the past year had been. Mr. Scorgie had been the most cheering and genial President that could be imagined. Those who had known him as an ordinary member of the Council liked him and the liking had been enormously increased since they had known him as President. He had won their affectionate regard and he was sure that they all hoped that they would see him some day again occupying the Chair as President.

The vote of thanks was carried by acclamation.

Mr. Norman Scorgie said, that if during his year of office he had maintained, to the satisfaction of the Society, the high traditions which had always surrounded it, he could assure the meeting that he was more than pleased. It was with extreme diffidence that he allowed his name to be put forward as President of the Society. Not that he had any misgivings as to the feelings of members, but because of his knowledge of his own imperfections and shortcomings and the few moments he had at his disposal which he could devote to the satisfactory performance of the duties. The year, as Mr. Shenton had reminded them, had not been an ordinary one ; it had been one in which their thoughts and their hearts had been elsewhere, but he trusted that, notwithstanding all the difficulties, it had been a pleasant year for members who had attended the meetings, listened to the papers, and contributed to the discussions. He hoped that everyone who had been fortunate enough to attend the meetings had derived some good from them ; trusting that his small contribution had added to the pleasure and had helped to put the Society on firmer ground and to promote its objects. He could only say from the bottom of his heart that he thanked the members very much indeed for the kind vote of thanks which they had accorded to him.

The **President** then delivered his

Presidential Address.

On taking for the second time the office of President it is once again my duty to thank my colleagues on the Council for nominating me, and the members generally for electing me, to this distinguished position. After some twenty years of service in the interests of the Society it is, I hope, unnecessary for me to reiterate my determination to devote myself unreservedly to its welfare. Nevertheless, I feel now almost as much diffidence in undertaking the responsibilities of the Presidential Chair as I did fourteen years ago when I faced them for the first time. Now, as then, however, my one hope of success lies in the support of the members, and I confidently appeal for that support on the grounds that, without mutual and willing co-operation between the members and the Council, the prosperity and usefulness of our Society must be seriously endangered.

On this occasion, as on the previous one, I enter upon my year of office in war-time, but while the South African war of 1902 merely affected the prestige of the nation in a distant colony, we are now engaged in a struggle where our very existence as a nation is at stake. Instead of what may relatively be described as a localized disturbance, in which an expenditure of 200 millions sterling and the loss of some few thousands of men appeared a fabulous (and, to some, an unjustifiable) cost, we are now incurring a similar expenditure and loss of life every six weeks, and for the moment it is impossible to foresee when this enormous wastage will cease. This, however, is not an occasion for enlarging upon the war, its causes, its purpose, or its probable result ; it is sufficient for me to remark that, under present conditions, the work of our Society cannot pursue its normal course, neither can we hope for any appreciable increase of membership or other important development of our usefulness and influence.

None the less would it be foolish and untrue to say that the Society cannot continue to justify its existence as it has done for a period of 62 years past. We still remain the only technical association which embraces every branch of engineering science and practice. We still offer to the younger members of the profession a unique opportunity for cultivating those faculties which are so indispensable to success, namely the art of writing technical papers, facility in communicating and acquiring information, and above all, the power to combine efforts to accomplish that which would be impossible to the individual working alone.

Status of the Engineering Profession.

At a time when civil, as distinguished from military or naval, engineering work is practically at a standstill, it seems only natural that our attention should be directed to such objects as, in normal times, are necessarily considered of secondary importance. I therefore make no excuse for directing a portion of my address to the much-discussed and thorny question of how to improve the status (or dignity) of our noble profession. A noble profession it undoubtedly is, for it includes in its ranks those who have contributed, and are contributing, to the material welfare of the community in every sphere of commercial, manufacturing or scientific activity. It is therefore only natural that the members should be jealous of its dignity and anxious that this should not suffer from the changing conditions under which it is now practised. It is, however, undeniable that in certain aspects, the dignity of the profession and the welfare of its members are alike suffering from defects due to the very rapidity of its development.

The term " engineer " is itself anomalous and misleading for it applies equally to one who has charge of an engine and to one who designs the most important works for " directing the great sources of power in Nature for the use and convenience of Man." In the one case, the root is common to that of the word " engine," and in the other, to that of the word " ingenious." Thus the profession of engineering includes greater diversity of talent and greater varieties of occupation than any other prefession, and some confusion and overlapping are inevitable.

The efforts so far made to eliminate this confusion and overlapping have tended in the direction of sub-division, and as this process has developed at hazard and without any systematic regulation, the result is, as might be expected, anything but satisfactory, and the public have great difficulty in differentiating between the various applications of the word " engineer." The first example of this sub-division is revealed in the term " Civil Engineer " which was applied in the first instance to distinguish civil from military engineers. A further sub-division occurred when the Institution of Mechanical Engineers developed proportions which proved this branch of the profession to be a large and important one ; and the fact that two large institutions labelled respectively " Civil Engineers " and " Mechanical Engineers " existed side-by-side, led gradually to a distortion of the original application of the term " Civil Engineer," and its use to distinguish those not engaged in the " mechanical " branches. This was, in respect of the " Status " of the profession, a very unfortunate development, because it tended to discount the influence of the Institution of Civil Engineers as the representative of the civil, as distinguished from the military, branch, and paved the way to the further sub-division of the profession into sectional societies and institutions, without any common interest or tie one with another.

This unfortunate tendency towards decentralization has been accentuated by the rapid development of new branches of engineering, and the increasing need for " specializing," and at the present time the term " engineer " is almost as wide and varied in its application as the term " man " itself.

It will, I think be conceded that the defects to which I have alluded, and particularly the public ignorance as to the nature, practice, and status of our profession in its various branches, are largely due to this excessive " decentralization," and the want of an institution which could be accepted without question as representative of the profession as a whole.

No doubt a very large number of engineers would readily admit (and in some cases, claim) that the Institution of Civil Engineers fully meets this want, but on the other hand, it is open to question whether this body, established " for the general advancement of mechanical science " is altogether fitted for the work involved in regulating the relationship between the various branches of the profession, and enlightening the public on the nature, practice, and status of the members thereof.

Having in view the objects I have already mentioned I venture to advance two propositions which seem to me to summarize the essential factors both in the problem itself and in its satisfactory solution ; *first*, that it is necessary to educate the public as to the functions, qualifications, rules of conduct and basis for remuneration of the various classes of engineers, and *secondly*, that this education of the public, as well as the settlement of questions affecting engineers in their relationship one to another, calls for the establishment of a new organization constituted on somewhat different lines from the various institutions at present existing, the chief purpose of which is the discussion of technical problems arising in the exercise of professional duties.

Let me here point out that in using the term " profession," I do not refer alone to the so-called " professional " branch, represented by " consulting engineers." Being myself a member of this class, I am only too well aware of the want of organization which is responsible for so many of the disadvantages under which consulting engineers in this country are working at the present time : but I am also aware that other branches of the profession are similarly, if not equally, in need of organization ; and I am convinced that no effective results can be obtained unless and until the various branches of the profession are brought together in some kind of federal union having as its main objective the consideration and settlement of those problems which are common to the whole profession. Chief among such problems are (1) the preliminary training necessary for entering the profession, (2) the relationship between the various sections, and particularly the delimitation of each, so that overlapping may be avoided ; and (3) the adjustment of the relations between the public and the profession as a whole.

With such an organization once established on comprehensive and representative lines, the subsequent sub-divisions could be effected with comparative ease. These should in my opinion be formed primarily on the basis of the nature of the services rendered rather than on the class of work involved ; thus the following sections would be the most obviously necessary, although others might be added as occasion arose, viz., consulting engineers paid by fees, manufacturing engineers and contracting engineers working for profit, engineer officials paid by salary, and employees of each section paid by salary, the last-named, of course, not including mechanics employed by manufacturing and contracting firms, who already have their trades-unions to look after their interests. In regard to classification according to the class of work involved, there exist Societies or Institutions representing nearly every branch of engineering work, and I do not suggest that any serious modification of these is either necessary or desirable. I do, however, suggest that the technical body representing each branch of the profession should make a point of standardizing the qualifications of the various grades of members so that the holding of any particular rank in a given institution should form a reliable guarantee of ability and experience, and warrant a reasonable standardization of the remuneration attaching to each whether by way of fees or salary ; also that each such technical body should be affiliated or otherwise associated with the proposed central organization.

No doubt the scheme here sketched in outline may seem somewhat " utopian " and I do not suggest that it would be easily carried into effect. Nevertheless, it seems evident that the engineering profession is large enough, important enough and sufficiently coherent, in spite of its many sub-divisions, to warrant an effort to accomplish the ends I have indicated, and while I do not consider that any existing society or institution, least of all the Society of Engineers, is so constituted as to be able to undertake such a gigantic task, I do not hesitate to suggest the possibility that, as the one Society embracing equally every branch of the profession, it would not be inappropriate nor impossible for the Society of Engineers to lay the foundation of an organization on the lines herein indicated.

In order to explain my purpose in making the above suggestions, I will briefly state some of the difficulties which at the present time affect three large and important sections of the profession ; viz.—(1) consulting engineers (2) manufacturing engineers and (3) salaried engineering officials.

Consulting Engineers.—The most prevalent difficulty affecting this branch arises from the very natural and excusable tendency of clients to secure advice in the cheapest market, and, by obtaining special quotations of fees in advance, to induce engineers to offer specially low terms in order to secure business. This has led some few members of the profession to adopt the very undesirable practice of competing for work, which practice has of course, encouraged clients to repeat the procedure. The only remedy for this state of affairs is the setting-up of a standard scale of minimum fees, and a general agreement among all consulting engineers never to accept less. This is no doubt a difficult matter, and the Council of the Institution of Civil Engineers have declared that they consider it a matter of great difficulty so to standardize fees, except to the extent of stating the usual charges to be 5 per cent upon the cost of works carried out, subject to some variations according to the size and nature of the work. Personally I am more sanguine as to the possibility of finding a practical and workable solution of this difficulty. The most important essential of such a scheme is the standardization of minimum qualifications attached to equivalent minimum scales of fees, and the provision of such qualifications and fees as will be applicable to junior members of the profession as well as to those with average or special experience.

Rules for professional practice in this country have been adopted by the Institutions of Civil and Electrical Engineers and the Association of Consulting Engineers on lines similar to those prevailing in America and elsewhere, but as breaches of these rules are not, happily, common, the profession generally has not derived much benefit from them. The only adequate solution of this difficulty, so far as it exists in this country, would be the formation of a close corporation with statutory authority to exclude defaulters, in other words, a Registration Scheme authorized by Act of Parliament. It is very doubtful whether any such scheme could be applied to such a complex profession as ours, and in the meantime the formation of small societies each with particular rules of conduct is open to the grave objection that the lists of members and rules of conduct issued by such bodies can be supplied to prospective clients, and thus constitute a species of advertisement, the use of which is a manifestly unprofessional proceeding. In my opinion the evils complained of can only be overcome by the preparation of a comprehensive code of rules of conduct, standards of qualifications and graduated fees which, being universally adopted, would automatically form the basis for a union of professional engineers, akin to the British Medical Association, which has rendered such valuable services to the members of that profession, as well as to the public they serve. Should such action be carried out by common consent, the question of establishing a statutory scheme of Registration would become open for consideration, although in my view it would be unnecessary.

Salaried Engineering Officials.—This large and rapidly increasing class is certainly as much in need of co-ordination and protection as that of consulting engineers. Here again the main object must be some kind of classification of qualifications with proportionate salaries, so that employers, particularly municipal authorities, may be protected from engaging incompetent men for the sake of economy in salaries, and the properly qualified officials may be protected from competition on the part of less competent men.

It is also important to establish, where necessary, and to develop the practice of making salaried appointments the subject of legal agreements in which the duties, hours, and other limitations or privileges are clearly set forth. It is only too frequently the case that officials are from time to time charged with additional duties and responsibilities for which they are not qualified, but which they cannot refuse without prejudice to their position ; this being as unsatisfactory to the employer as to the official. It is also manifestly unfair that salaried officials should be allowed to engage in private practice without some specific limitations as regards the time allotted to this work, and the use of the employer's office, materials and staff. It is also a fair claim on the part of consulting engineers in independent practice that salaried officials should not undertake private work at less than the minimum fees common in the profession and attaching to their particular qualifications and experience. Another point which requires attention is the protection of competent officials from personal hostility or annoyance on the part of individual members of municipal authorities, several cases of which have recently occurred.

Manufacturing and Contracting Engineers.—In this branch of the profession there is perhaps less need for interference than in those previously mentioned. Nevertheless there is a growing tendency on the part of contractors to undertake purely consulting work. This is by no means necessarily the fault of the contractors, but arises most frequently from a (natural) tendency on the part of customers to obtain professional advice free of direct charge, oblivious of the fact that such services must be eventually charged for indirectly. There may at first sight appear to be some difficulty in fixing a clearly defined limit between an estimate for certain works or plant, and professional advice, but it is surely possible to educate the public, and at the same time to secure the co-operation of contractors, in differentiating between *independent* professional advice which should be strictly reserved to consulting engineers paid by fees, and quotations for specified goods or work which alone lie within the sphere of the contractor or manufacturer trading for profit.

These are a few of the great problems which the engineering profession should face, and I cannot help thinking that there are many members of it, who, during a period when their usual activities are suspended, might with advantage devote their attention to the solution of the difficulties involved.

In concluding my referenee to this subject I will only add that the views I have expressed are not necessarily those of the Council as a body, neither are the suggestions which I have made above put forward as representing the policy to be pursued by this Society. The Council are anxious to receive assistance in the form of suggestions or opinions from all engineers, whether members of this Society or not, and my purpose has been to summarize the difficulties to be overcome, and to suggest a means for accomplishing the end in view, which may lead to useful discussion, and possibly to joint action on behalf of the whole profession, which is the essential factor in any advance towards that end.

Water Supply.

On turning to that branch of the profession with which I have been most intimately associated, it is perhaps not without interest to recall the remarks contained in my Presidential Address of 1902, if only for the purpose of observing the progress made in the intervening years. This is the more easy because in a Blue Book recently issued by the Local Government Board the present position in regard to some of the more general features of the water supply of this country, to which I specially referred in 1902, will be found to be clearly stated. From the preliminary memorandum preceding the statistical information contained in this it will be seen that there has been no general Water Supply Legislation during this interval, although the Blue Book itself may be considered as a preliminary step in this direction. It is a matter for regret that the Legislature should exhibit such palpable reluctance to deal with problems of a domestic character, and yet devote so much energy to political problems which are, in many cases, of much less importance to the well-being of the community at large.

Take, for example, the question of responsibility for providing a public supply of water. As far back as 1878, the Select Committee on the Public Health (Water) Act of that year made several recommendations calculated to facilitate the action of local sanitary authorities in securing or providing supplies of water for their districts, but for the most part similar recommendations are repeated in the Blue Book above referred to, thus showing that defects admitted in 1878 remain uncorrected in 1915.

Similarly in the case of areas of supply, and the difficulties of combining sanitary districts for water supply purposes, the present condition of affairs is practically the same as in 1902 except for a few isolated cases where joint water-boards have been created for large and populous areas. As Mr. Henry C. Adams (Vice-President) has pointed out in his Presidential Address to the Institution of Municipal Engineers, there is urgent need of legislation to facilitate, and under certain circumstances to compel, the union of adjacent rural parishes for schemes of water supply.

In connection with the allocation of sources of supply and the need for a permanent Central Authority to deal with this matter on certain well-defined principles, in contradistinction to the present method of settling such questions in Select Committees of the Houses of Parliament, the position has remained unaltered in spite of many reiterated recommendations of Royal Commissions, Government Departments and Parliamentary Committees to say nothing of influential Public Bodies such as the County Councils Association, the Institution of Water Engineers, and the like.

In regard to municipalization some progress has been made by private legislation transferring particular undertakings to the local authorities of the district, but no general legislation has been promoted to transfer to local authorities areas which, although included in the statutory limits of company undertakings, are not supplied with water on account of the available revenue in water-rates being less than the amount prescribed in the Waterworks Clauses Act, 1847, nor to permit local authorities to make up the prescribed revenue out of the general rate.

On all such general questions the position has not changed since I last occupied this Chair, and it must, I think, be admitted that, in matters of this kind, our national tendency to wait for a serious emergency before remedying known defects, has proved a great disadvantage. At the present moment, however, it may be confidently hoped that, after the rude awakening which the nation has experienced in connection with its most vital interests, the policy of *laissez-faire* will be entirely abandoned, and when relieved from the strain imposed by the war, the nation (and particularly the Legislature) will make a point of dealing promptly with all domestic questions in connection with which defects are discovered or improvements are called for.

In regard to water-works there is at the moment little progress to record, as expenditure on public works of this nature has been ruthlessly curtailed on account of the war. Nevertheless I feel bound, not only in the interests of my confrères, but also in the public interest, to suggest that water and sanitary authorities should not allow this period of "suspended animation" to be wasted. There are many cases in which urgent works will have to be undertaken or resumed immediately the war is over, and the relatively small amount of expenditure involved in the preparation of plans and specifications might be incurred with advantage at once. Where the local water authorities do not take the initiative in this direction, it may reasonably be urged that the Local Government Board should use their influence to press forward the preliminary work in question. I would even suggest that in most cases engineers would be glad to do the work now rather than later on, if only to occupy such of their assistants as are beyond the military age, and that the payment of fees could be deferred until the war is over.

In connection with works of water supply, recent practice has exhibited little in the way of novelty. Public attention is of course attracted mainly by the larger works, particularly those involving the construction of impounding reservoirs, but meanwhile the most intricate and interesting problems are constantly being solved under circumstances which are not favourable to publicity, and the engineer engaged on smaller works has the satisfaction of gaining experience in many complex details of waterworks practice which escape the notice of those absorbed in designing larger and more costly schemes. I therefore desire to urge upon such of my confrères as may be practising in small works to make a point of publishing their experiences in the form of papers, and to realize that, with the exception of the Institution of Water Engineers, this Society is the most appropriate means of securing their publication, and discussion.

While but little novelty is to be found in works of water supply generally, a great deal of useful and unobtrusive research has been carried on in connection with the filtration of supplies derived from sources liable to pollution. The increasing use of mechanical filters may be taken as the practical issue of this research, but it must not be assumed that this practice alone affords a solution of the problems involved. The experiments carried out by Dr. Houston for the Metropolitan Water Board have proved the enormous and unexpected effects of simple storage, and have also demonstrated the efficiency of treatment with an excess of lime followed by sedimentation and efficient filtration, thus involving a softening of the water at the same time. The intelligent combination of old and new methods is also well illustrated by the successful application of mechanical filters in conjunction with slow sand filters, also by the Puech system, in which the filter beds are arranged in sequence, commencing with those where gravel is used as the filtering medium and ending with those where fine sand is employed.

While dealing with the question of filtration it may be worth while to consider the broader question of the conditions necessary to warrant a water being considered as suitable for ordinary domestic use, or, in other words, as " a pure and wholesome water " as defined in the Waterworks Clauses Act, 1847. In a paper presented to the Institution of Water Engineers in June, 1914, Professor S. Delépine, of the Manchester University, describing the standard results to be required of any modern filtration plant, suggested some tests for filter effluents which may be accepted as a safe and practical definition of what " a pure and wholesome water " should be. I therefore venture to reproduce these tests as being applicable (with some obvious exceptions) to all water supplies whether artificially filtered or not.

Essential conditions :—

1. The water viewed in a 2ft. tube shall be of a pale blue colour, or retain not more of any original yellow or brown discoloration than an amount capable of giving to the water a bluish green colour.
2. The water viewed in a 2ft. tube shall be clear.
3. The water when heated to 30°C. and to 100°C. shall be free from any appreciable smell.
4. One cubic centimeter of filtered water shall never contain more than 100 bacteria, capable of growing in three days on peptone bouillon gelatine (+10), incubated at 20°C.

5. Any quantity less than 10 c.c. of the filtered water shall not contain the bacillus coli communis.
6. The filtered water shall have no material action on bright pure lead after being in contact continuously for 24 hours at a temperature of 20°C. (By material action is meant an action causing the taking up by the water of more than one part of lead in 2,000,000 parts of water. When the lead is completely immersed, the ratio between the surface of lead and the volume of water is as one to four).
7. The hardness of the filtered water as tested by Clarke's method shall not, except in special cases, exceed 10 per 100,000.
8. The amount of alumina in the filtered water shall not exceed the amount of alumina in the raw water.
9. The filtered water shall contain no copper, lead, zinc, or more than traces of iron.

Conditions regarding which the scientific referee may exercise his discretion:

10. 100,000 parts of filtered water should not take more than 0.05 parts of oxygen from permanganate of potash in acid solution in 4 hours at 27°C.
11. Free ammonia in the filtered water should not exceed 0.02 parts in 100,000.
12. The albuminoid ammonia in the filtered water should not exceed 0.005 parts per 100,000.

Gas Supply.

Reference to the subjects mentioned in my previous Address will afford striking evidence of the progress made in this branch of engineering during the past 14 years. What was then described as a "fair prospect" of "seeing the flatflame burner displaced by the incandescent burner" is now, for all practical purposes, an accomplished fact. The then vague possibility of heating power being substituted for illuminating power as a criterion of statutory test is also now a normal practice, although the cost of manufacture under modern conditions has not been reduced to the extent which at that time seemed probable. Nevertheless a marked increase has been obtained in the yield of gas per ton of coal, the then normal average of 10,000 cub. ft. per ton having advanced to a figure approaching 13,000 cub. ft. per ton, without of course including water-gas. The supervision of consumers' fittings, which in 1902 was something of a novelty, is now universally undertaken, generally at charges which barely cover the actual cost, and the hiring out of stoves, fires, and fittings combined with the use of "slot" or "prepayment" meters, described then as a "recent practice" is now developed until the amount of capital employed in this way forms a very appreciable proportion of the whole capital employed, and the proportion of "slot" consumers has risen from an average of 25% to an average of 50%. High-pressure lighting for streets, shop-fronts, and large open or covered spaces has steadily developed; maintaining, if not improving, its position relative to electric light. While the Scott-Snell automatic high-pressure lamp, which in 1902 seemed to have a brilliant prospect of success, has failed to stand the test of time, the inverted gas burner, then a novelty, is now in common use and has more than fulfilled the expectations of its progenitors.

The most conspicuous developments in connection with carbonizing plant are vertical retort settings (both continuous and intermittent), and the extended use of machinery for handling coal and coke, particularly machines for charging and drawing horizontal retorts.

In regard to administration, the delivery of gas through high-pressure trunk mains, enabling it to be conveyed long distances in mains of relatively small diameter, has tended to develop the centralization of carbonizing works, and the amalgamation of adjacent undertakings, and further development in this direction appears likely in the future.

The war has opened a very brilliant future for the important by-product, tar, which has secured an immediate market as a source of the high explosives used in munitions, and has also, owing to the temporary cutting off of the supply of chemicals and dyes from Germany, and the scientific development of this industry in Great Britain which will, it is hoped, follow, obtained a still brighter prospect for the future.

The application of gas to manufacturing processes requiring a readily-controlled source of heat has also made rapid strides, and in every respect the future prospects of this important industry are such as the energy, ingenuity and resourcefulness of English gas engineers have amply merited.

THE ENGINEERING PROFESSION.

In conclusion it may not be inappropriate at a time like the present to make a few observations on the engineering profession generally. In the earlier portion of this address I called attention to the first sub-division of engineers into "civil" and "military." At the present moment we see this distinction disappearing. While war has become more than ever a question of armaments and munitions, the personal factor being more and more dominated by the mechanical, the functions of the civil and the military engineer have tended to merge one into the other ; indeed, the functions at present peculiar to the military engineer are very limited, and those formerly restricted to the civil (or perhaps I should here say the mechanical) engineer are being utilized on a very extensive scale as, for example, in the construction of ships of war, guns (both military and naval), the manufacture of munitions of war, as well as in the numerous ancillary services, such as military transport, field-telephones, air-ships, aeroplanes, sanitary appliances and the provision of pure water supplies for the troops in action.

Our profession is therefore becoming daily more important and comprehensive. Scientific discoveries and mechanical inventions are ever extending the range of the engineers' duties ; every economic development of manufacturing processes, every effort to reduce the cost of production, and thus even the political emancipation of the working classes which involves the substitution of machinery for hand labour as an essential to the maintenance of commercial activity, in fact, every modern development of civilization brings with it an increasing demand for the services of the engineer.

Let us, therefore, as members of "The Society of Engineers" realize the dignity and importance of our profession, and endeavour to make our Society not only a means of technical instruction and professional advancement in its various branches, but also a medium for bringing those branches together in a common and enthusiastic effort to maintain and develop the dignity, prosperity and respect which the importance and universality of our work and influence rightly deserve.

VOTE OF THANKS.

Mr. J. W. Wilson said that as the senior Past President it was his great privilege to propose a very hearty vote of thanks to Mr. Griffith for his address. He had that evening brought to bear upon the very important matters he had touched upon, a ripened experience. With regard to the status of engineers he had brought forward some valuable suggestions which were the outcome of that experience, and he had made interesting references to those branches of the profession which were more immediately under his control. Much as they had appreciated his former address they would value more the one they had just listened to. Mr. Griffith had occupied the presidential chair in 1902, and had then retired on to what had been called "the comfortable shelf of the Past Presidents" ; but in his case this did not mean that he had taken no further part in the affairs of the Society. Members of the Council knew how he had interested himself in the intricate questions which occurred when the amalgamation between the Society of Engineers and the Civil and Mechanical Engineers' Society took place a few years ago. He had made the "shelf" a position from which to do very hard work for the Society; and, having been president once he had gone through the whole process again until he had, for the second time, reached that honourable position. He was sure that he had before him a very successful year. Some lines, which were wrongly attributed to Shakespeare, came to his mind:—

"'Tis not in mortals to command success,
But we'll do more than this, we will deserve it."

Their president well deserved success in his year of office; and knowing and appreciating him as he did, he was sure that he would achieve it.

Mr. W. B. Esson said that he had much pleasure in seconding the vote of thanks. He would endorse what had fallen from the lips of Mr. Wilson as to the zeal which Mr. Griffith had displayed with regard to the Society. There was not the slightest doubt that he would have a successful year.

The motion was carried by acclamation.

Mr. Percy Griffith said that he greatly appreciated the kindly reception given to his address. He had listened to a good many presidential addresses and he was in a position to extend to the meeting his hearty sympathy, because such addresses when they touched subjects with which the members were not familiar, were apt to be tedious. To listen to a person reading his own composition was often somewhat of a trial to human nature and it was very good of the meeting to forget that and to express itself as pleased at having to go through the ordeal. The points which he had raised were some of them debatable, and he was sorry that he was not able to invite discussion that evening. Perhaps the Council would be able to support some of the suggestions which he had brought forward, and in that case, he hoped the Society might thereby be able to take a position in the engineering world which, at any rate from its age, it deserved, but very much depended upon the support of the members in extending the usefulness of the Society. He felt sure that the kindness which had prompted them to support him that evening would be sufficient to induce them to continue the good work, and lose no opportunity of developing and extending the influence of the Society.

6th March, 1916.

Mr. PERCY GRIFFITH, M.Inst.C.E., President, in the Chair.

SEWAGE AND ITS PRECIPITATION: FACTS AND FALLACIES FROM LABORATORY AND PRACTICAL TESTS

By Reginald Brown, M.Inst.C.E., M.I.Mech.E., F.S.I., F.R.San.I.

The treatment of sewage by chemical precipitation has been so frequently discussed that one would have thought that nothing fresh could be said on the matter. It is, however, as well to remember that although in these days of bacteriological treatment the subject of chemical precipitation is seldom heard of so far as discussions before professional societies are concerned, the system is still in vogue in a large number of places; indeed, in the report of the recently completed labours of the Royal Commission on Sewage Disposal the opinion was expressed that it is almost essential with some sewages (containing trade wastes) to adopt chemical precipitation as a preliminary treatment, and even in the case of domestic sewages such a treatment materially aids the removal of the suspended solids, and hence facilitates subsequent filtration. The tendency on the part of certain authorities to regard chemical precipitation as an obsolete form of preliminary treatment was not justified by the experience of the Royal Commission, although, as was to be expected, the Commission could not lay down any *precise* rules as to when chemical precipitation should be adopted, neither could they arrive at the relative cost and efficiency of the various precipitants on the market. Neither the results obtained nor the cost given in the Commissioners' reports can be compared, so far as precipitants are concerned, with any degree of satisfaction, as sufficient information is not given to enable one to do this. The strength of sewage and the amount of suspended solids present therein vary so much in different towns that in practice no definite comparison can take place either as to the cost or the results. It is clear that no fixed rule as to cost and effect can be applied, but that each sewage requires different treatment, or—applying this generally accepted dictum to chemical precipitation—if a particular chemical is good and economical at one place it does not follow by any means that the same chemical used with another sewage and under different working conditions will attain equal results at the same cost. This point, the author wishes to emphasize, cannot be too much insisted upon, for a mere statement that a chemical has been found to be both economical and efficient at any particular place is of no comparative value unless it is qualified by information as to the quality of the sewage dealt with. Of course, it may be said that engineers responsible for the maintenance of sewage disposal works ought, from their own knowledge, to be able to satisfy themselves of the value of any particular precipitant, but the author is afraid that in a good many instances a precipitant is felt to be satisfactory so long as the effluent from the final process satisfies the river authorities. A precipitant may have been used for several years with very satisfactory results when viewed from this standpoint, but it ought to be within the power of every sewage engineer to state definitely which is the best chemical to use for the particular sewage being dealt with by him ; this can, however, be done only by conducting careful experiments under actual working conditions, and not taking for " gospel " all that is claimed for any particular method.

Although the composition of different sewages varies to such a large extent at different works, and even at the same works at different periods of the day, it is recognised that the amount and nature of the organic impurities present in the tank liquor determines the ease or difficulty of final purification, or, speaking generally, the greater the percentage of purification in the tanks the greater the ease with which final purification can be obtained. The impurities in every sewage consist of those in suspension and those in solution, and the object of preliminary treatment in tanks, whether by chemical precipitation or otherwise, is to reduce the amount of suspended solids to the lowest possible figure, leaving the majority of the solids in solution to go forward to be oxidised on the land or by filters.

For the purpose of this paper one need deal only with simple sedimentation and chemical precipitation, as the author wishes to differentiate between those suspended solids which will " deposit " of themselves by reason of their specific gravity, and those solids which will either require chemicals to precipitate them or will, in the absence of chemicals, have to pass forward to be dealt with by natural or artificial filters. The amount of " deposition " taking place in any tank will vary according to the shape and capacity of the tank as compared with the flow, and, of course, also the amount of suspended solids present in the sewage and capable of being deposited. So far as the author is aware no definite rule has been laid down as to the design of tanks for any particular sewage, although it would not appear to be difficult, in some cases at least, to do so, if and when the proportion of suspended solids and solids in solution, and the character of the former had been ascertained. No doubt experiments have been carried out under actual working conditions for the purpose of ascertaining the extra degree of purification obtained by the addition of chemicals, but at this stage the author desires to refer briefly only to those carried out at Dorking by the Royal Commission. The sewage experimented upon was of domestic character of average strength, and the tanks used were rectangular in shape, 18ft. 6in. long by 4ft. 6in. wide by 4ft. 9in. deep, the sewage being passed through them on the continuous flow principle, one tank being used as a "sedimentation" tank and the other for chemical precipitation. The sewage in both cases was screened before entering the tanks. The results of the experiments are detailed below :—

	Crude Sewage.		Continuous Flow. (Tank Liquor.)		Precipitation. (Tank Liquor.)	
	Parts per 100 000.		Parts per 100,000.		Parts per 100,000.	
	Min. Max.	Aver.	Min. Max.	Aver.	Min. Max.	Aver.
Ammoniacal Nitrogen ...	2·63–5·69	4·65	2·33–7·96	4·97	2·00–7·72	4·76
Albuminoid Nitrogen ...	0·56–1·66	1·00	0·37–1·40	0·84	0·23–1·14	0·59
Total Organic Nitrogen ...	1·17–3·11	1·92	0·54–2·84	1·69	0·41–2·82	1·33
Oxidised Nitrogen ...	0·00–0·76	0·11	0·00–0·28	0·02	0·00–0·62	0·07
Total Nitrogen	4·51–8·58	6·72	3·16–9·62	6·59	2·39–9·29	5·97
Oxygen absorbed at 27° C. (at once)	1·20–3·41	2·38	0·66–3·66	1·97	0·25–2·72	1·26
Oxygen absorbed at 27° C. (in 4 hours ...	6·37–14·77	10·01	3·30–14·67	7·75	1·59–11·85	5·71
Chlorine ...	5·58–16–64	8·71	—	—	—	—
Solids in suspension ...	11·7–32·8	21·50	3·6 –23·7	9·39	2·9 –16·7	6·71

The principal point that the author wishes to note here is that the solids in suspension which were deposited without the addition of chemicals were (21·50 – 9·39 =)12·11 parts per 100,000, and that only an additional (9·39–6·71 =)2·68 parts per 100,000 were due to the precipitant added (in this case lime) so that the degre of purificaton due to the chemicals, if calculated on the crude sewage, would be 69%, but if calculated on settled sewage—on the basis of the solids in the effluent from the continuous flow tank—would be 29%. Hence, strictly speaking, the only admissible way to obtain a correct account of work done by any particular precipitant is to settle the sewage first. In laboratory tests this is a simple operation, but, as will be seen hereafter, the results obtained in a laboratory do not agree with those obtained in general working. There are many factors which come into play in the everyday work of purifying sewage which cannot be copied in laboratory tests, for these latter can only be carried out on a particular sample over a particular period ; the author therefore suggests that laboratory tests do not show correctly what might be the results obtained from actual treatment at a sewage works. In dealing with the value of precipitants the Royal Commission pointed out that precipitation by chemicals has the effect of throwing down, as sludge, a considerable proportion of the colloidal matter present, and as this matter exercises a clogging effect upon the filters, the degree of reduction in its amount is an important part of the preliminary treatment, and this is where the value of precipitants is felt. Again, although in some cases precipitation shows but slight additional purification over simple sedimentation, it must be borne in mind that it is more difficult to obtain this *additional* purification than it is to secure all that precedes it.

Although the author has for many years had a preference for sulphate of alumina and lime as a precipitant for the preliminary treatment of sewage, under circumstances which require precipitants, he is not one of those who think that it is impossible to obtain an equally good precipitant, and he is always prepared to try new precipitants if it can be shown that their use would be advantageous from the point of view of economy and efficiency. Such an opportunity occurred a short time ago, and it may be of interest for the experiments to be placed on record as they show the result of ferric salts and salts of alumina. The materials used were (*a*) ferric sulphate, (*b*) ferric sulphate and lime, and (*c*) sulphate of alumina and lime. Ferric sulphate can be obtained both in solid and liquid forms, and although one agrees that it is preferable, if not necessary, to apply chemicals to sewage in a liquid form, it is just as well, and certainly more economical, to make the solution at the sewage works rather than to pay carriage on water. This point is emphasised by the analysis of a sample of liquid ferric sulphate as shewn below :—

Ferric sulphate $Fe_2(SO_4)_3$ ...	18·53%
Free sulphuric acid (H_2SO_4) ...	3·95
Insoluble matter	traces (from 0 to 5%)
Water (by difference)	77·52
	100·00

This is the analysis of a liquor with a strength of 60 Twaddell at a temperature of 60° Fahr. With ferric sulphate in a solid form there must, of course, be a certain amount of water (combined moisture) present, but the proportion is small compared with the above. To show the composition of this material the author gives the following analyses by different analysts.

FOUR ANALYSES BY DIFFERENT ANALYSTS SHOWING PERCENTAGE COMPOSITION OF SOLID FERRIC SULPHATE.

	1.	2.	3.	4.
Ferric sulphate ...	60·0	62·1	*	37·5
Ferrous sulphate ...	5·1	—	—	4·0
Free sulphuric acid...	18·8	11·7	3·04	18·0
Ferric oxide and silica	7·0	5·9	—	—
Alumino sulphate ...	4·8	—	—	—
Moisture	4·3	19·6	14·70	22·2 (at110 C. 9·5 (combined)
Alumino (Al_2O_3) ...	—	0·7	1·30	—
Ferrous oxide (FeO)	—	—	0·43	—
Sulphur (free) ...	—	—	1·26	—
Sulphates	—	—	54·10	—
Insoluble matter ...	—	—	4·69	8·8
Oxide (Ferric Fe_2O_3)	—	—	17·97	—
Silica...	—	—	3·49	—
	100·0	100·0	—	100·0 per cent.

* The amount of ferric sulphate in this analysis is given as 64·33%

Whilst the proper interpretation of an analysis evidently depends upon the knowledge possessed by the interpreter, the author considers that it would be better for chemists to standardise the form of their analyses, so that engineers may be able to compare one with another without themselves having a deep knowledge of chemistry. These remarks apply also to the two analyses of sulphate of alumina given below :—

(*a*)	Per Cent.
Insoluble in water ...	·08
Ferric oxide	·85
Alumina	14·03
Sulphuric anhydride ...	35·10
Water (by difference) ...	49·94
	100·00

(*b*).	Per Cent.
Insoluble in water ...	·08
Ferric sulphate... ...	2·12
Alumina sulphate ...	47·04
Free sulphuric acid ...	1·00
Water (by difference) ...	49·76
	100·00

Ferric Sulphate.—Experiments were tried in the laboratory to ascertain what quantity of chemicals should be used for the particular sewage under test, and it was found that, to all appearances, the results pointed to 4 grains per gallon as being the required amount. The ferric sulphate was deposited in a channel and dissolved by the sewage itself, and the actual proportions found to be 3·93 grains per gallon, calculated on a dry weather flow of 1¼ million gallons. The curves (Fig. 1) show the times at which the precipitants were added, and the amount at those times. The experiments were extended over a continuous period of 16 days, and during that period eleven average daily samples

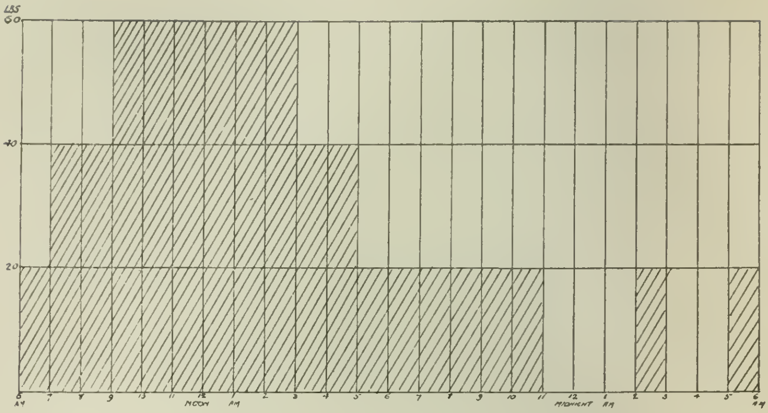


FIG. 1.—ADDITION OF FERRIC SULPHATE TO SEWAGE.

of the sewage during its various processes of purification were analysed with the following average results :—

TABLE 1.

FERRIC SULPHATE.

Average Results of Eleven Samples in parts per 100,000.

	Crude Sewage.	Detritus Tank Effluent	Precipitation Tank Effluent	% Purification on Crude Sewage.	Effluent from Filters.	% Purification on Crude Sewage.
4 Hours' Oxygen Absorption	6·88	6·65	4·00	41·86	0·73	89·39
Free and Saline Ammonia (in terms of N)	3·22	—	3·29	—	0·079	—
Albuminoid Ammonia (in terms of N) ...	0·613	—	0·456	25·61	0·078	87·28
Chlorides (in terms of Cl)	33·00	—	30·4	—	28·2	—
Suspended Solids ...	20·1	16·3	3·9	80·6*	2·2	89·06
Iron (in suspension) ...	1·25	—	1·38	—	0·45	—
Do. (in solution) ...	0·51	—	1·16	—	0·11	—
Colloidal matters (measured by the 4 hours' Oxygen Absorption)	2·56	—	2·15	16·0	—	—
Nitrites	—	—	—	—	·007	—
Nitrates	—	—	—	—	2·39	—

Rainfall during period = ·11 + ·06 + ·14 + ·15. Total ·46in.
Maximum Temperature of Air 102° Fahr.
Minimum ,, ,, 52° ,,

* If calculated on the detritus tank effluent (partially settled sewage) the percentage purification is 76·69.

The percolating filter effluent was averaged for the week before the suspended solids were estimated.

The physical conditions of the sewage during its purification were noted. The tank effluent was invariably of a dark colour, and if kept quiescent for a few hours and then disturbed it evolved a disagreeable odour, mainly due to hydrogen sulphide; this odour was particularly noticeable after the restarting of the percolating beds fed by revolving sprinklers. One remarkable feature was a decided red colour on the surface of the percolating beds, due probably to unprecipitated iron passing out with the tank liquor under treatment. During the working of the filter beds the surfaces were greyish black, presumably due to sulphide and sulphate of iron, and during resting periods (six hours daily) the surface exhibited a rusty red colour due to the oxidation of the ferric sulphate by sun action. It is fair to assume that a similar action would take place inside the beds, not of course, by the action of the sun, but by the oxidising agency of bacteria and with the moisture present forming ferric hydrate, a spongy compound, which in course of time would cause "ponding." From a comparison of the amount of iron in the sewage and that passing out of the tank effluent it will be seen that only about half of the ferric sulphate was taking any part in the actual precipitation, and hence the reason of the quantity passing on to the beds. It was also of interest to note that most of the higher forms of life washed from the filters were dead or nearly so, so that it is fair to assume that the lower forms of life would also suffer, and as effectual purification is mainly dependent upon these latter, this assumes an important aspect.

Ferric Sulphate and Lime.—These experiments extended over a continuous period of six days, the lime used being Clay Cross lime. The curve (Fig. 2) shows the times at which the precipitants were added and the amounts at those times.

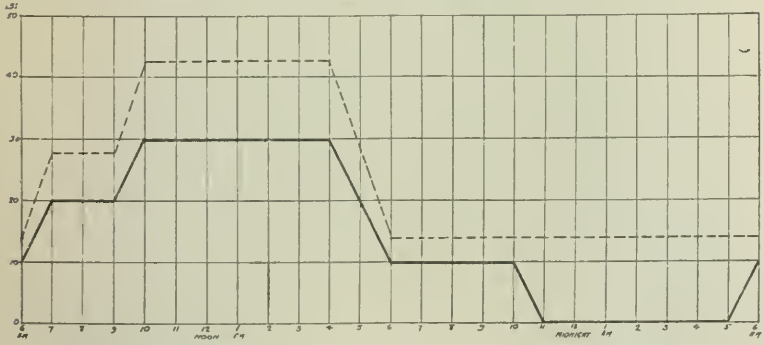


FIG. 2.—ADDITION OF FERRIC SULPHATE AND LIME TO SEWAGE.

(*Lime shown by dotted line, Ferric Sulphate by continuous line:* 14 *lb. of Lime to* 10 *lb. of Ferric Sulphate*).

The quantities worked out at 2·03 grains of ferric sulphate per gallon and 2·80 grains of lime per gallon. During this period five average daily samples of the sewage during its various processes of purification were analysed with the following average results :—

TABLE 2.

FERRIC SULPHATE AND LIME.
Average Results of Five Samples in parts per 100,000.

	Crude Sewage.	Detritus Tank Effluent	Precipitation Tank Effluent	% Purification on Crude Sewage.	Effluent from Filters.	% Purification on Crude Sewage.
4 Hours' Oxygen Absorption	6·53	5·77	3·71	43·2	0·60	90 66
Free and Saline Ammonia (in terms of N)	3·79	—	3·57	—	0·058	—
Albuminoid Ammonia (in terms of N) ...	0·77	—	0·48	37·7	0·085	88·7
Chlorides (in terms of Cl)	32·4	—	32·5	—	31·00	—
Suspended Solids ...	20·96	13·7	4·2	80·0*	1·8	91·4
Iron (in suspension) ...	1·50	—	0·94	—	0·46	—
Do. (in solution) ...	0·58	—	0·69	—	0·15	—
Colloidal matters (measured by the 4 Hours' Oxygen Absorption)	2·48	—	2·00	19·3	—	—
Nitrites	—	—	—	—	0·008	—
Nitrates	—	—	—	—	3·26	—

Rainfall during period, Nil.
Maximum Temperature of Air. 80° Fahr.
Minimum ,, ,, 52° ,,

* If calculated on the detritus tank effluent (partially settled sewage) the percentage of purification is 69·35.

The percolating filter effluent was averaged for the week before the suspended solids were etimated.

As in the case of using ferric sulphate alone, the tank effluent was of a very dark colour, but the addition of lime prevented the liquid becoming putrescent, and hence the smell was absent. As might be expected, and as confirmed by the analyses, the amount of iron passing out of the tank liquor was considerably reduced. Comparing the results of ferric sulphate alone and ferric sulphate used in conjunction with lime it is obvious that the addition of lime is not only necessary but beneficial.

Sulphate of Alumina and Lime.—These experiments extended over a continuous period of sixteen days, as in the case of those in which ferric sulphate alone was used. The proportions used were 1·9 grains of sulphate of alumina to 2·8 grains of lime per gallon. Six blocks of sulphate of alumina were used daily, the average weight of each being ½ cwt., one block being used at each of the following times : 6 a.m., 9 a.m., 11.30 a.m., 2 p.m., and 5.30 p.m., one block being reserved for the night (about 10.30 p.m.), while the lime was used uniformly from 6 a.m. to 10 p.m. throughout the day. The blocks of sulphate of alumina were placed in the sewage channels, and the lime was mixed with water (milk of lime), and run into the sewage prior to the addition of the sulphate of alumina. During the period eleven average daily samples of the sewage during its various processes of purification were analysed with the following average results :—

TABLE 3.

SULPHATE OF ALUMINA AND LIME.

Average Results of Eleven Samples in parts per 100,000.

	Crude Sewage.	Detritus Tank Effluent	Precipitation Tank Effluent	% Purification on Crude Sewage.	Effluent from Filters.	% Purification on Crude Sewage.
4 Hours' Oxygen Absorption	7·83	7·46	3·35	57·2	0·57	92·7
Free and Saline Ammonia (in terms of N)	4·57	—	4·23	—	0·063	—
Albuminoid Ammonia (in terms of N) ...	0·93	—	0·48	48·4	0·099	89·4
Chlorides (in terms of Cl)	34·7	—	32·5	—	30·9	—
Suspended Solids ...	25·1	16·9	2·2	91·2*	1·7	93·2
Iron (in suspension) ...	1·99	—	0·69	—	0·35	—
Do. (in solution) ...	0·73	—	0·54	—	0·22	—
Colloidal matters (measured by the 4 Hours' Oxygen Absorption)	2·82	—	1·69	40·1	—	—
Nitrites	—	—	—	—	0·004	—
Nitrates	—	—	—	—	3·66	—

Rainfall during period = ·08 + ·10 = ·18.
Maximam Temperature of Air = 104° Fahr.
Minimum ,, ,, 48° ,,

* If calculated on the detritus tank effluent (partially settled sewage) the percentage purification is 87.

The percolating filter effluent was averaged for a week before the suspended solids were estimated.

In using sulphate of alumina and lime the physical conditions of the sewage during its various processes of purification showed a remarkable change, the resulting tank effluent being clear and without smell, while the liquor was not putrescent, and, as shown by the analyses, the iron in the tanks was reduced.

One is now able to compare the average percentage purification obtained by the chemical precipitation tanks and filters when using the precipitants described ; for convenience these are set out in the table below :—

TABLE 4.

COMPARATIVE PERCENTAGE PURIFICATION.

(The figures in the brackets refer to the final effluent from the percolating filters, the others to the tank effluent.)

	4 Hours' Oxygen Absorption.	Albuminoid Ammonia.	Suspended Solids.	Colloidal Matters.
(1) Ferric sulphate (alone) ...	41·86 (89·39)	25·61 (87·28)	80·6 (89·06)	16·0
(2) Ferric sulphate and lime	43·2 (90·66)	37·7 (88·7)	80·0 (91·4)	19·3
(3) Sulphate of alumina and lime	57·2 (92·7)	48·4 (89·4)	93·2 (93·2)	40·1

On inspection of these figures the following particulars should be noted :—

Four Hours' Oxygen Absorption.—Precipitant No. 3 shows an increase of 15½% over No. 1 on the tank effluent and of 3% on the effluent from the percolating filters.

Albuminoid Ammonia.—Precipitant No. 3 shows an increase of 22¾% over No. 1 on the tank effluent and of 2% on the effluent from the filters.

Suspended Solids.—Precipitant No. 3 shows an increase of nearly 11% over No. 1 on the tank effluent and of 4% on the effluent from the filters.

Colloidal Matters.—As previously mentioned, these solids in partial or pseudo-solution are very important. Precipitant No. 3 shows an increase of 24% over No. 1 tank effluent.

It is hoped that these figures will make the results from the use of each chemical quite clear. They are, however, the outcome of ordinary everyday working, and as it was the desire of the author to compare these with the results obtained in the laboratory, further experiments were carried out by settling average daily samples of crude sewage for two hours, and syphoning off the quiescent liquid. The only comparative test carried out was that for oxygen absorption, the sewage and tank effluents being portions of those included in Tables 1 and 3. The results are shown in Table 5 :—

TABLE 5.

Tests on Settled Sewage and Tank Effluents.

	Ferric sulphate alone.		Sulphate of alumina and lime.	
Test. No.	Settled Sewage.	Daily Averages of Tank Effluent.	Settled Sewage.	Daily Averages of Tank Effluent.
	Parts per 100,000.		Part per 100,000.	
1.	5·52	3·80	4·52	3·60
2.	4·24	3·80	4·56	3·48
3.	4·04	3·80	4·64	3·16
4.	4·36	3·68	4·64	3·32
5.	4·56	4·20	5·08	3·32
6.	4·40	3·88	4·76	3·24
7.	3·80	4·24	4·72	3·32
8.	4·20	4·00	5·04	3·76
9.	4·52	4·16	4·52	2·96
10.	4·16	4·00	4·44	3·44
11.	4·08	4·44	4·64	3·24
Aver.	4·35 *	4·00	4·69 *	3·35

Note.—The figures in Tables 1 and 3 give 6·65 and 7·46 respectively for partially settled sewage from detritus tank, due to continuous flow; Table 5 is quiescent settlement in the laboratory.

It will be noted that in Nos. 7 and 11 tests (Table 5) with the ferric sulphate the settled sewage gave better results than the respective tank effluents, but, on the whole, show 8% improvement in the tank effluent over the settled sewage. With the sulphate of alumina and lime treatment on no one occasion was the settled sewage better than the tank effluent, and, on the whole, the improvement reached 28·5%. If it is borne in mind that this percentage shows the actual work done by the precipitants as calculated by the four hours' oxygen absorption test, and taken in conjunction with the colloidal matters and suspended solids tests, the value of the comparison of the two precipitants becomes obvious.

To test the matter still further the author carried out a long series of comparative tests by means of an acidulated solution of permanganate, and in all cases the sulphate of alumina showed remarkable superiority. Although being perfectly satisfied with these results in actual working, samples were submitted to an analyst for experiment in the laboratory.

These were samples taken every hour of the day, in proportion to the flow from the two separate inlets into the works, and sealed up in two vessels before leaving the works for delivery to the analyst, who had instructions to mix the two liquids in the proportion discharged from the respective inlets. The results of the analyses were reported as follows :—

TABLE 6.

Showing Results of Laboratory Tests on a Large Single One Day's Sample of Crude Sewage treated with (*a*) Sulphate of Alumina and Lime and (*b*) Ferric Sulphate alone in the same Quantities as in Working Tests.

	Crude Sewage.	Sulphate of Alumina and Lime.		Ferric Sulphate alone.	
		2 hours' Settlement.	5 hours' Settlement.	2 hours' Settlement.	5 hours' Settlement.
		Parts per	100,000.	Parts per	100,000.
		Unfiltered.			
Oxygen ...	3·51	2·26	2·07	2·18	2·09
Free ammonia ...	5·95	5·61	5·61	5·44	5·27
Albuminoid ,,	1·08	0·54	0·54	0·45	0·45
Suspended matter	34·2	13·88	12·04	10·36	8·60
Total solids ...	185·8	168·8	166·6	161·8	159·7
		Filtered.			
Oxygen ...	1·61	1·56	1·56	1·60	1·60
Free ammonia ...	5·95	5·10	5·10	5·44	5·44
Albuminoid ,,	0·38	0·38	0·25	0·27	0·27
Total solids ...	154·2	154·0	154·0	153·0	150·3
		Percentage Purification.			
		Unfiltered.			
Oxygen ...	—	35·6	41·0	37·9	40·4
Free Ammonia	—	5·7	5·7	8·6	11·4
Albuminoid ,,	—	50·0	50·0	58·3	58·3
Suspended matter	—	59·6	64·8	69·7	74·9
Total solids ...	—	9·1	10·3	12·9	14·0
		Filtered.			
Oxygen ...	—	3·1	3·1	—	—
Free Ammonia	—	14·3	14·3	8·6	8·6
Albuminoid ,,	—	—	34·2	28·9	28·9
Total solids ...	—	—	—	0·8	2·5

From the percentage purification figures of the laboratory tests the analyst concludes that the advantage appears to be in favour of ferric sulphate.

To make the results comparable either the cost or the efficiency must be reduced to a standard, and as the former was more easily ascertained than the latter, the author takes it as a basis in the curves given below, in which the analytical results are obtained from the tables previously given and the costs calculated from the following prices per ton :—Sulphate of alumina, 58s. 9d.; Ferric sulphate, 45s. ; and Clay Cross lime, 22s. 6d.

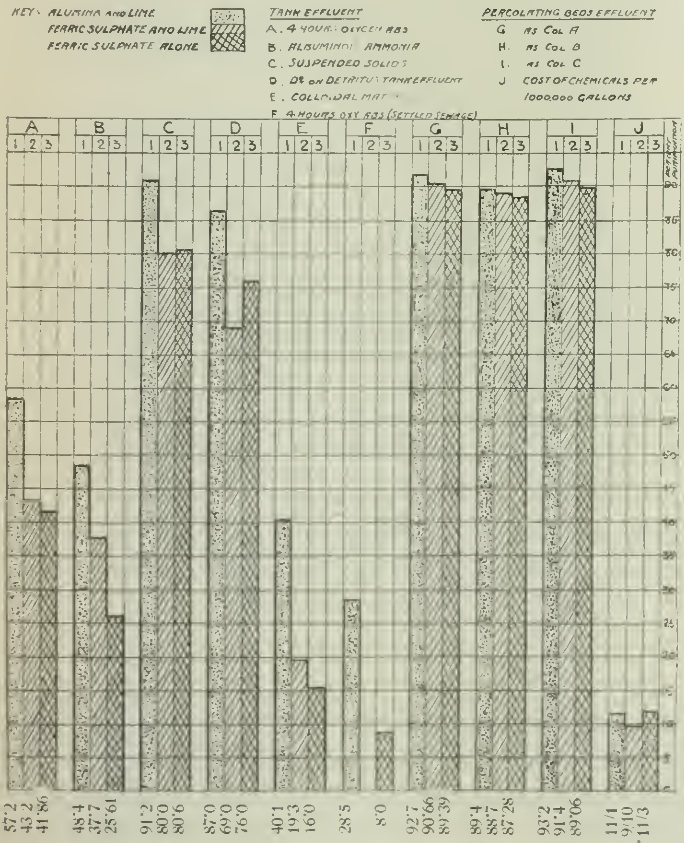


FIG. 3.—PERCENTAGE PURIFICATION ON CRUDE SEWAGE (unless otherwise indicated).

The author will now briefly describe the works and the class of sewage dealt with. The sewage experimented upon was from a district containing factories, the dry weather flow on weekdays being 1¼ million gallons per day, made up as follows :—

			Gallons.	Gallons per head.
Inlet A.	(1)	From water supply	500,000	18
	(2)	,, subsoil water	500,000	18
Inlet B.	(3)	,, Trade wastes	100,000	
	(4)	,, public institutions ...	150,000	54
			1,250,000	

On Sundays the flow was reduced by the amount due to trade wastes, flow from public institutions, etc., to about one million gallons per day.

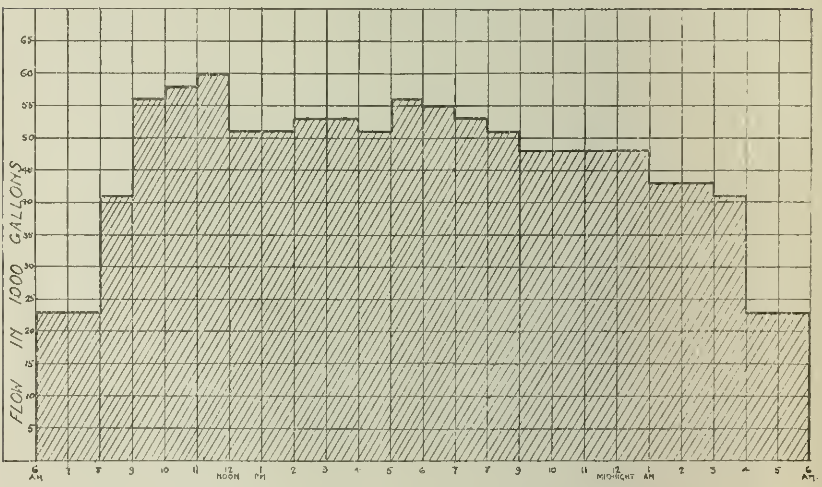


FIG. 4.—AVERAGE DAILY FLOW OF SEWERAGE.

Fig. 4 shows, as nearly as can be ascertained, the varying flow of the sewage in an average day, the volume due to the flow from the public institution being omitted, as the latter is pumped at different hours as shown on the pumping charts (Figs. 5 and 6).

The strength of the sewage may be gathered from the analyses given in the tables; although not taken for these particular experiments, typical analyses of Items 3 and 4 (trade wastes and from public institutions) are given below :—

TABLE 7.

Typical Analyses.

	No. 3.	No. 4.
	Parts per	100,000.
Free and saline ammonia (in terms of N.) ...	1·4	4·8
Albuminoid ammonia ,, ,,	0·695	0·51
Chlorides (in terms of Cl)	232·0	15·00
Four hours' oxygen absorption	5·73	5·2
Ether extract (fat)	10·8	—

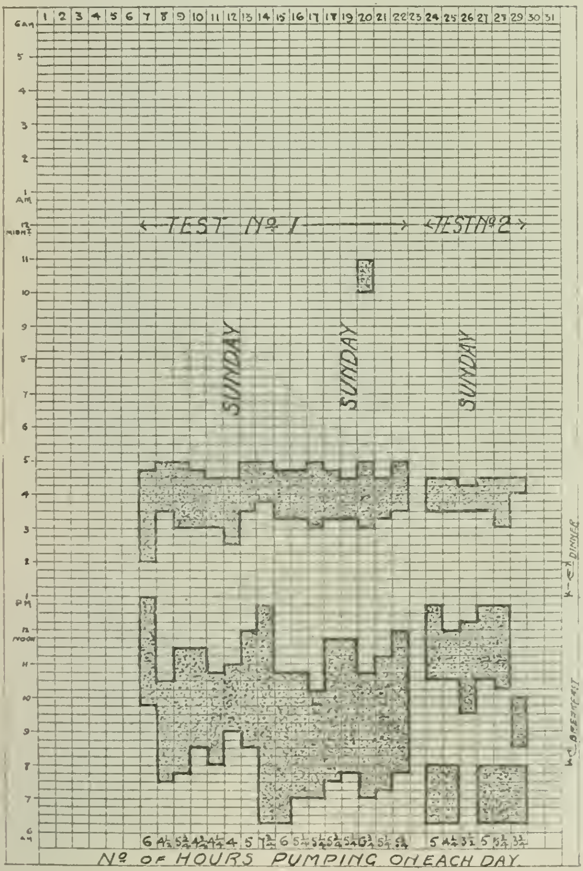


Fig. 5.—Times of Pumping.

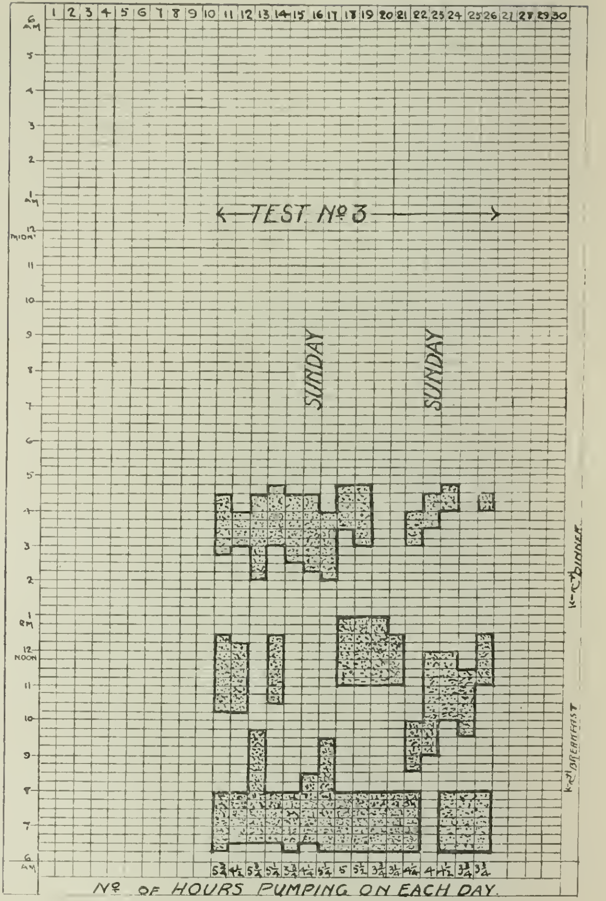


Fig. 6.—Times of Pumping.

Treatment.—The sewage from Inlet B is screened, and first passes into two low-level tanks with a total capacity of 57,000 gallons, and is lifted by means of 5in. centrifugal pumps and through an 8in. rising main to be treated with the sewage from Inlet A. The pumping being spread over varying periods during the day, as previously mentioned. The sewage from Inlet A reaches the works by gravitation, and after screening meets the flow from Inlet B, and the mixture passes through two tanks having a total capacity of 25,000 gallons; the average dry-weather flow through these tanks is therefore at the rate of

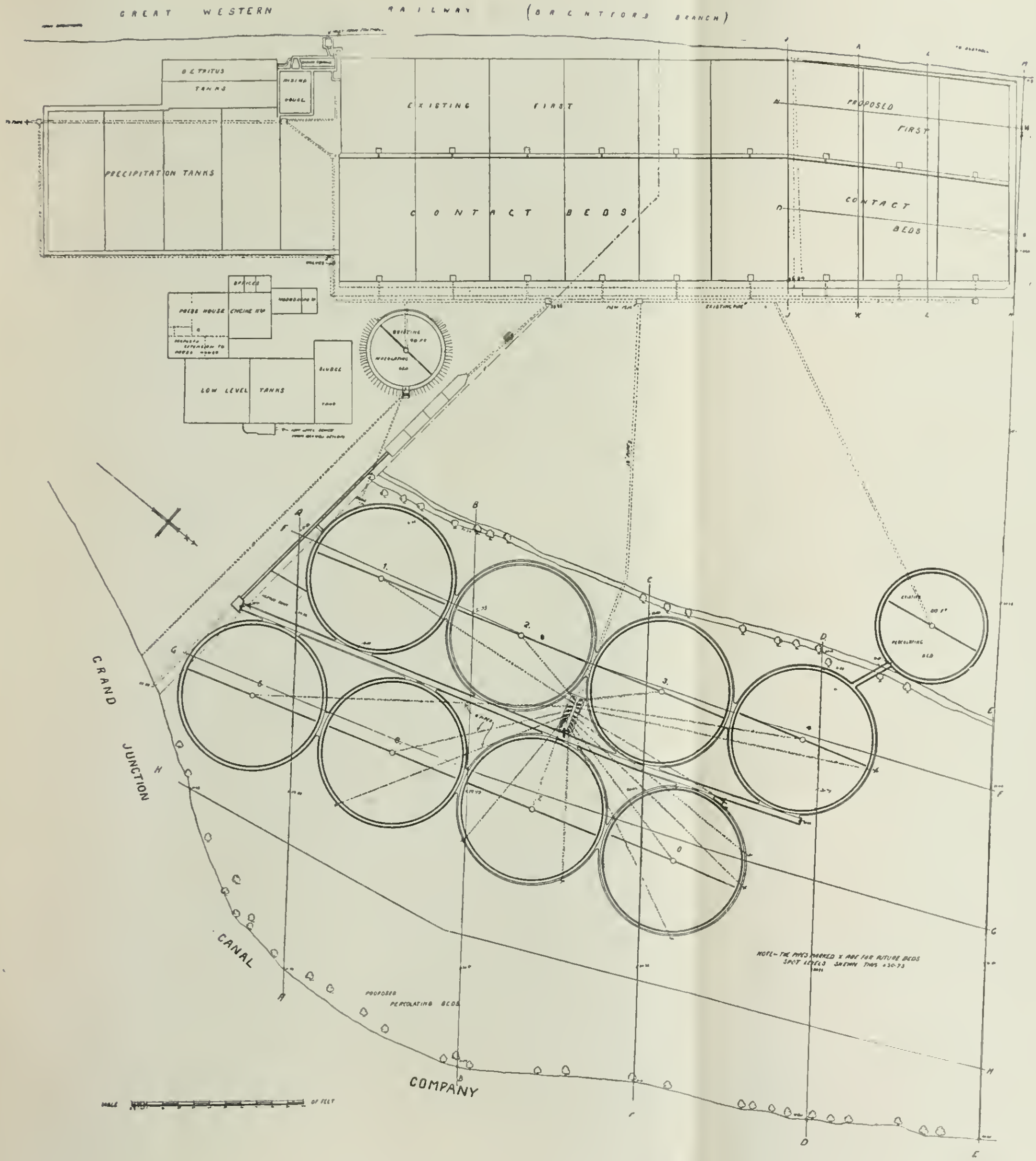

GREAT WESTERN RAILWAY (BRENTFORD BRANCH)
DETRITUS TANKS
MIXING HOUSE
PRECIPITATION TANKS
EXISTING FIRST CONTACT BEDS
PROPOSED FIRST CONTACT BEDS
OFFICES
WORKSHOPS
PRESS HOUSE
ENGINE Hse
PROPOSED EXTENSION TO PRESS HOUSE
LOW LEVEL TANKS
SLUDGE TANK
EXISTING 90 FT PERCOLATING BED
1.
2.
3.
4.
5.
6.
7.
8.
EXISTING 90 FT PERCOLATING BED
A
B
C
D
E
F
G
H
J
K
L
M
GRAND JUNCTION CANAL COMPANY
PROPOSED PERCOLATING BEDS
NOTE—THE PIPES MARKED X ARE FOR FUTURE BEDS
SPOT LEVELS SHOWN THUS +20.73
SCALE OF FEET

Fig. 7.—Plan of Sewage Works.

2·3 c. ft. per second. Assuming that the velocity multiplied by the area gives the discharge, then the tanks having a cross sectional area of 65 superficial feet, the velocity of the flow will be ·0354ft. per second. The tanks are 60ft. in length. No chemicals are mixed with the sewage until after it has passed through these small tanks, they being used as detritus tanks only. When using ferric sulphate alone the chemical was placed in a carrier at the outlet end of these detritus tanks. When the sulphate of alumina and lime experiments were being carried out, the milk of lime was added to the sewage *after* passing through the detritus tanks and the blocks of sulphate of alumina were placed in a channel between the first and second precipitation tanks about to be described. The precipitation tanks are four in number, working in series, each having a channel on the division walls through which all the tank liquor passes. Each tank has a capacity of 150,000 gallons, and a cross sectional area of 330 sq. ft., the velocity of flow being about ·007ft. per second. The channels between the tanks having a cross sectional area of only 4 sq. ft., the velocity of flow through these will be at the rate of 0·56ft. per second. The total length over which the sewage must pass in going through the precipitation tanks and carriers is 800ft. Each tank is provided with scum boards at its outlet, and, as might be expected, the greatest proportion of sludge is deposited in the first tank. The tank liquor is then passed through straining filters and on to percolating beds treating 17¾ galls. per sq. yd. per hour, or nearly 12 galls. per cubic yard—working 18 hours each day and resting 6 hours. Care was taken to have the precipitation tanks cleaned out for each test so that the results should not be affected by the use of previous precipitants. The author need only remark here that the sludge from Test No. 1 was too difficult to press satisfactorily even with the addition of a larger percentage of lime. For the better understanding of the works at which the experiments were carried out the illustrations show a plan of the works (Fig. 7), a view of the tanks (Fig. 8), and a view of the percolating beds (Fig. 9).

The author thinks it is quite clear from the results of the given tests that to arrive at the comparative value of precipitants it is necessary to compare the results as ascertained under *actual working conditions* and not from a single or a small number of samples analysed or experimented upon in a laboratory. Laboratory experiments are only valuable in so far as they indicate what can be expected under particular conditions, but as these conditions can probably never be duplicated in actual working, the latter must take precedence of the former. Practice without theory is the "body without the spirit," while theory without practice is the "spirit without the body"; for a complete in-

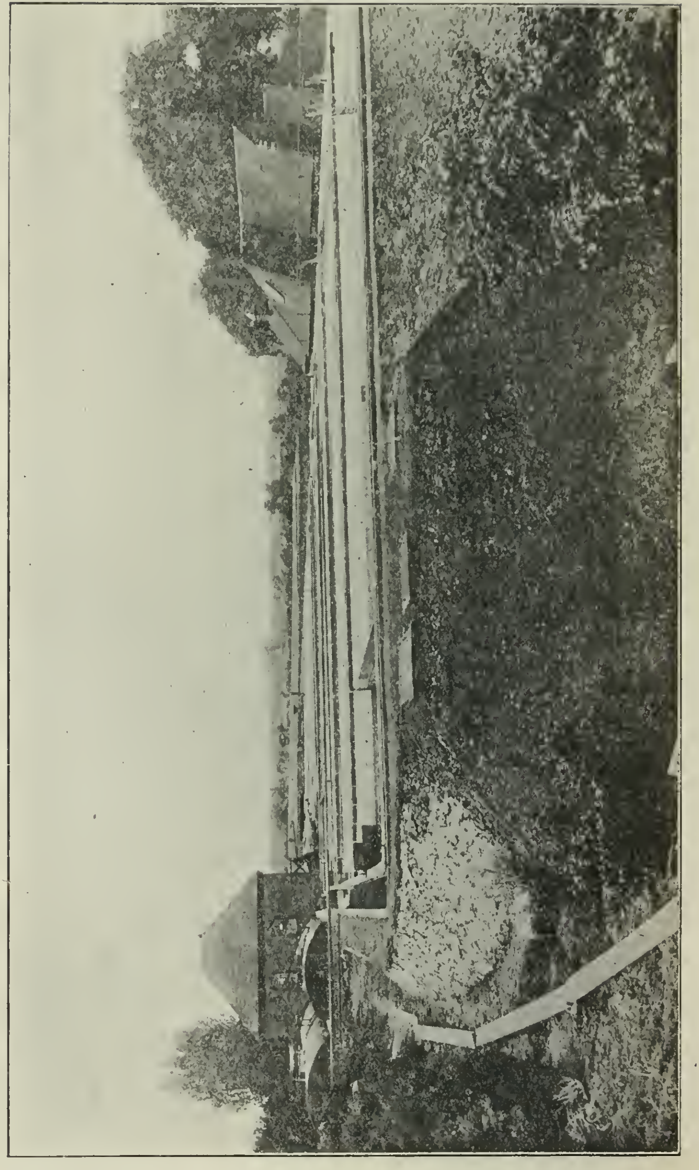


FIG 8.—VIEW OF PRECIPITATION TANKS.

vestigation both are necessary. Theory lays down that under particular circumstances certain results will accrue. Practice says—at least, in so far as sewage disposal is concerned—that the particular circumstances laid down by theory are never present, and the results which theory says should accrue do not materialise in practice because of this.

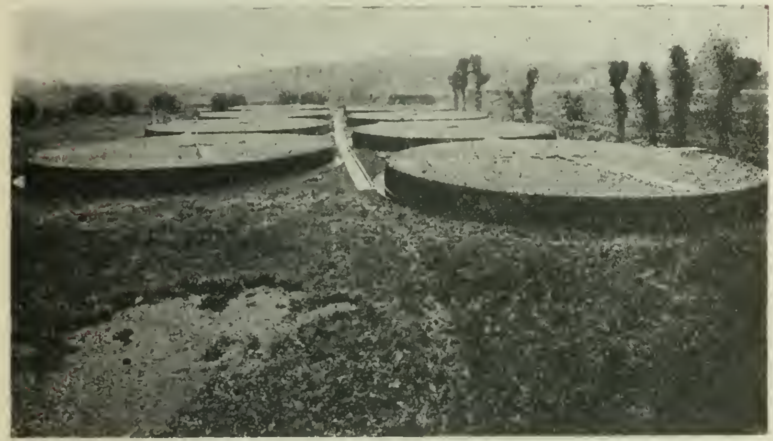


FIG. 9.—VIEW OF PERCOLATING BEDS.

The facts stated in this paper are given as the results of conscientious experiments, and with the hope that they may be of some service to others besides the author, who has tried to describe as fully as he is able the conditions under which precipitants in general, and those experimented upon in particular, ought to be tested for comparative purposes, so as to find the most economical and efficient for a particular type of sewage.

The author cannot conclude this paper without expressing his great appreciation of the valuable assistance rendered by and co-operation of Mr. J. H. Edmondson, F.C.S., whose careful and painstaking workings are shown summarised in the various analyses (in Table 1-5), and without whose assistance it would not have been possible for the author to have stated the results so clearly.

The **Author** added that he wished members to deal with the question of the value of lime added to a particular precipitant, and its action in stopping smell; and also with the question whether the tests laid down in the paper were the correct tests to follow.

The **President** moved a hearty vote of thanks to the author for his paper, and said he had been discussing with Professor Fleming, of University College, the question of the co-ordination of scientific research and its practical application in the national interest. Professor Fleming said he thought that the Government ought to provide particularly for the remuneration of those persons who undertook research work on their own account, whether it was practical or scientific or both. The Professor felt that those who spent time, energy, and ability in preparing the results of technical tests and giving them to the world ought not to be left, as they were at present, without hope of recognition or reward. Those remarks were very appropriate on the present occasion, because the author had shown himself to be one of the large class who were working gratuitously and without hope of recognition or reward in the public interest. He (the President) was not an expert in the subject of the paper, and he was not attempting to value the results which the author had placed before the meeting. He would leave that to those who knew the subject better, but he felt that, whatever the value of the work done by Mr. Brown might be, it had been done in the spirit to which he (the President) had referred. The very least that the meeting could do for the moment—(it was possible that more might be done on a future occasion)—was to tender its hearty thanks to the author.

The vote of thanks was carried by acclamation.

DISCUSSION.

Mr. F. Wilkinson said that the more he knew about sewage the more he found there was to learn. He agreed with the author that no two effluents were alike, and that co-operation with chemists was absolutely necessary. The engineer alone was not sufficient. The author gave four analyses by different analysts showing different percentages. His own experience was that that always occurred, and that to arrive at a fair analysis and comparison it was necessary to get at least three chemists to make the analyses.

Another point that he agreed with the author on was the adding of chemicals to the effluent in solution and not in solid form. His experience was that better results were obtained in that way. If they added alumino ferric in the solid form it dissolved more rapidly on one day than on another. Possibly the sewage was almost the same each day, and in that case different results were obtained. He would like to have seen the results of experiments on this sewage with lime alone. Perhaps the author could give some analyses for the last two or three years.

Mr. S. W. Barnes said it appeared to him that the paper was almost entirely a chemist's paper, so he did not like to discuss it. He knew the very great interest that Mr. Brown took in his work, and the very able chemist that he had to assist him. Mr. Brown was very fortunate in that respect, because it was only of late years that surveyors had had such assistance. His own works were too small to allow of the expense of having such a highly skilled manager as Mr. Brown had at Southall--Norwood, and he (the speaker) had not had the opportunity of getting out such very valuable figures as Mr. Brown had got out. Mr. Brown had rendered a very useful service in going to the trouble of getting them out, and to the further trouble of reading a paper giving the results of his work.

Mr. J. H. Edmondson (Southall-Norwood) said that Mr. Brown had said practically all that could be said on the subject, but he would like to draw attention to one paragraph in the paper which nobody seemed to have taken Mr. Brown to task over. On page 41 Mr. Brown said, " Whilst the proper interpretation of an analysis evidently depends upon the knowledge possessed by the interpreter, the author considers that it would be better for chemists to standardise the form of their analyses, so that engineers may be able to compare one with another without themselves having a deep knowledge of chemistry." All analysts were not sewage experts, and sulphates of alumina and iron were used in other industries besides sewage disposal. If engineers would ask analysts when submitting samples for the analysis to be expressed in any particular way it would, undoubtedly, be done.

It seemed very peculiar that ferric sulphate should prove a success in the laboratory, but not a success on a practical scale.

On p. 37 he considered the author gave the text of his paper, " If a particular chemical is good and economical at one place it does not follow by any means that the same chemical, used with another sewage and under different working conditions, will attain equal results, at the same cost," or in other words because ferric sulphate did not work satisfactorily at Southall-Norwood, there was no reason why it should not prove efficient at any other works. There were two important features bearing on the precipitation of sewage. One was the tankage, and the other was the class of sewage under observation. With regard to the laboratory experiments ferric sulphate proved to be equal to, if not better than, sulphate of alumina and lime ; so it stood to reason that ferric sulphate was quite adaptable for the Southall-Norwood sewage, and consequently it must be the fault of the plant that success was not attained on a practical scale. If they considered the theory of precipitation, the reason for the failure might be ascertained. They all knew that, if salts of alumina and iron came in contact with an alkali as in sewage disposal they were precipitated as hydroxides capable of carrying down the colloidal substances in pseudo solution along with the suspended solids, to the bottom of the tank. The action was supposed to be both chemical and physical. It was chemical in such a way that the hydroxides formed an insoluble compound with the albumins present in the sewage, and physical in so much that when the iron or alumina was released from solution into suspension, or when they were in the nascent state, they had the power of attracting other colloids and so coagulating. Further, if they considered the hydroxides of iron and alumina it was a well-known fact that hydroxide of iron would more easily go into a colloidal state than alumina. When they shook a solution containing hydroxide of iron in a bottle they would find that it would settle very badly indeed, while aluminium hydroxide would settle fairly rapidly. Now, compare this fact with the working of the tanks at Southall-Norwood. They added the precipitants to the sewage in the channel, after leaving the detritus tanks, physical and chemical combinations took place, and coagulation was practically complete before entering No. 1 tank where 50 per cent. of the solids deposited. After passing through this tank there was an immediate rush down a narrow channel into No. 2 tank and likewise into No. 3, and finally into No. 4. He maintained that it was this fierce agitation which allowed the iron hydroxide to go back into the colloidal state and free the colloidal solids which it had attracted, and so pass out of the tanks in the tank effluent. As he had said, and as Mr. Brown had said, the objects of the experiments at Southall-Norwood were to find the particular precipitant for the particular plant, and not to find a particular plant for any particular precipitant.

Mr. Henry C. Adams said, that a man who made researches similar to those which Mr. Brown had made, and who presented them in an easily understandable form, rendered a great service to his profession. He thought that the most valuable part of the paper was contained in the tables, but it was quite impossible to comment upon them without first giving to them the very careful consideration which they undoubtedly deserved. It was well understood that what might be right in Southall-Norwood might not be suitable in other places. In making investigations of the character of those under review, certain facts were brought out which acted as guides to other investigators, and, therefore, their value was far greater than was apparent on the surface.

He noted that the ferric sulphate was added in a solid form, that is to say a block of ferric sulphate was put into the channel, so that it was dissolved by the sewage. Generally speaking that method of dissolving solids necessitated very careful mixing afterwards in order that the chemical should permeate all parts of the sewage. He did not know to what extent this system was responsible for the fact that half of the ferric sulphate passed out of the tanks, or rather half of the iron passed out of the tanks, apparently not having done any work at all. When the lime was added the amount of the solids precipitated was naturally increased and the amount of iron escaping was considerably reduced. It would be interesting to ascertain whether a more thorough mixing would not lessen the amount of iron escaping from the tanks.

REPLY.

The Author, in replying, said that he thanked the meeting most sincerely for the vote of thanks which had been accorded to him. One could not expect, on a paper such as this, the amount of discussion that would take place on a paper which was purely descriptive. He quite understood that the paper needed to be in the hands of members for a considerable time, and to be thoroughly studied, before there could be a full discussion upon it. Therefore he was not disappointed because there had not been more discussion, although he thought that the discussion always brought out facts which an author had overlooked, and that he was able to learn a considerable amount from it.

As Mr. Edmondson had said, the principal idea of the experiments was not to design a plant for precipitants, but to find out the precipitant for a particular plant. Many members knew from their own experience that chemicals were offered to them as excellent precipitants for the particular sewage with which they had to deal, by people who knew nothing whatever about the conditions under which those precipitants had to be used. The chief idea of the paper was the testing of particular precipitants at existing works, and to find which was the best under ordinary working conditions.

Mr. Adams had drawn attention to the fact that in the second test, ferric sulphate with lime, there was less iron passing out of the tanks than in the first test with ferric sulphate alone. He (the author) was sure that Mr. Adams would quite understand what was said in the paper upon that question when he was able to study it at leisure. They would find in the second test only just over two grains of ferric sulphate per gallon put in, whereas in the first test there were nearly four grains of ferric sulphate put in, so that, of course, there was considerably less iron going out of the tanks in the second test. When he mentioned that the idea of the tests was to ascertain which was the best precipitant, it also answered the question as to whether better results could have been obtained if the material had been added in a liquid form. Every sewage engineer would agree that it was better to mix the precipitant in a liquid form, instead of a solid, but the practice at the works in question had always been to put solid blocks in the sewage itself, and let them be dissolved by the sewage. That being the practice with sulphate of alumina, it was also applied in the case of ferric sulphate, so that both should be working under exactly similar conditions.

If there had been chemists present he probably should have been pulled to pieces, and slated very considerably, for drawing attention to the want of uniformity in analyses. He thought that it was possible for chemists to arrange their analyses in one form. He also thought that, probably, the answer to that would be that if they wanted an analysis in proper form it was for the engineer to say what he wanted, but in many cases the engineer, not being a chemist, would not know in what form he desired the analysis, so far as the precipitating constituents were concerned. The better way was to go to a chemist versed in sewage disposal, and not to chemists versed in water analysis only, or those versed only in the general chemical trade.

Mr. Wilkinson had mentioned the question of tests with lime. Tests with lime had been carried out, but they had not been by any means satisfactory compared with the tests shown in the papers. They did not give the same amount of purification.

If, when members had time to go through the results of the experiments, they desired to have any further information on the points raised by them, he should be delighted to give it if they would write to him. He, however, thought that the paper contained all that was required to be known as to the conditions of the experiments.

With regard to the suggestion of a visit to the Southall-Norwood sewage works, on behalf of the Southall-Norwood Council he would be delighted to invite members of the Society to visit the works on any afternoon that they pleased. In conjunction with Mr. Edmondson the chemist, he would show them anything that there was to be seen. There was also a very nice laboratory at the works which would be of interest to them.

Mr. Wilkinson said, that he would like to mention the one hundred thousand gallons of trade wastes referred to in the paper. Would the author let members know of what the trade wastes principally consisted.

The Author said, that on page 51 he had given the analyses of the trade wastes. In that analyses 232 parts chlorides to 100,000 gallons were given. There was certainly no actual mention of what the trade wastes were, but he had given the analyses so that the members might see the nature of the wastes. If the fat and the salt together were taken he thought that they would guess what the trade waste was. It was something nearly approaching to butter.

The President said that, on behalf of the Council of the Society, he wished to express appreciation of the invitation which Mr. Brown had given members to visit the works in the summer.

Mr. H. Alfred Roechling wrote saying that although the paper did not contain any new facts or theories it was, nevertheless, an interesting one, and the author was to be commended on the great care he had employed in trying to settle the question of the preliminary treatment of sewage in a particular case.

He fully agreed with the author that the only rational and intelligent way to settle questions of this kind was by careful experiment, and he was glad the author was not hampered in this by so-called economic considerations or what should be called a penny wise and pound foolish policy. Formerly sanitary authorities had demurred at spending money for experiments, but the truth that to proceed without them was probably a waste of the ratepayers' money was now being more and more recognised.

Experiments of this nature ought to be undertaken in a broad and comprehensive spirit and without preconceived notions, otherwise the results obtained might be altogether misleading. It had been stated that an experiment was a question addressed to Nature, and they would all probably realise that the answer was likely to be returned in the same spirit in which it was asked.

When making such experiments the observer must possess a full knowledge of the various processes of sewage treatment and their limitations, and he must further be intimately acquainted with the requirements of the case at the present time, and their likely modifications in future.

It was probably best to proceed by way of laboratory experiments at first, and when these had led to some definite results it was absolutely essential to try the suggested method on a proper working scale. The conditions under which laboratory experiments were carried out differed more or less from the conditions under which a certain treatment had to work in everyday practice, and for this reason it would be very unwise to apply the laboratory results without any modifications to working conditions and base upon them an expensive large plant.

It was further essential that the experiments should be conducted for a sufficiently long time, so as to include all the changes to which sewage was subject, and which occurred both daily and periodically in long intervals. Short experiments must, by their very nature, be inconclusive.

But even the best experiments will be no guarantee for the success of the new works unless skilled and careful management is secured for them from the outset. The best of works will eventually collapse if the management is careless and inefficient, as the results of the treatment require to be watched daily and carefully ascertained by some kind of analysis, so that any mistakes could be rectified at once. To imagine that the plant will practically run itself was equivalent to courting disaster.

He quite agreed with the author that science and practice must go hand in hand, by which he understood, that scientific knowledge must be applied in a practical common sense way. Rule of thumb methods were all very well, when they were applicable, but in sewage treatment they would lead to bad results, which was tantamount with waste of public money. They must bear in mind that in sanitary matters the most efficient methods were always the cheapest in the long run.

If chemists could agree on some standard form of analysis it would be a great advantage to those who had not the expert knowledge of interpreting the various ways in which analyses were expressed, or of correlating them, but he thought the reason of this difference in determining and expressing analytical results was the fact that up to now all their methods were only approximate and far from exact. The various ways of determining analytical facts had probably each its own advantages applying to various sets of conditions, and it was, perhaps, quite natural for skilled observers, to adhere to their own particular method of making and expressing analyses.

In connection with this he had seen it stated, that the sense of smell in man had been proved to be at least a million times more delicate than the most refined of physical tests, such as the spectroscope, and probably a thousand million times more delicate than the most refined tests of bacteriology. If this statement was correct, and he had no reason to doubt it, they would see that their tests and the apparatus used in them were far from perfect.

The author had stated that the removal of colloidal matter was one of the principal points to be aimed at in any preliminary chemical treatment, and he had shown that with sulphate of alumina and lime he had succeeded in removing about 40 per cent. of colloids: This treatment, according to the prices given in the paper, entailed an annual expenditure of about £250, which capitalized represented a sum of about £5,000.

He thought, however, that the removal of colloidal matter could be done more efficiently and probably cheaper either in a Travis tank or by the activated sludge process.

As regards the Travis tank he had before him analytical figures from Norwich and Luton, which gave the following percentage purifications :—

	Percentage Purification. on raw Sewage.		
Constituents.	Norwich.		Luton.
Suspended matter	96	92·9	94·7
Colloidal matter	59	39·8	45·2
Albuminoid Nitrogen	72	73·9	70·5
Oxygen absorption	77	73·7	39·5

These figures referred to a considerable number of analyses, all of which had been very carefully made in average daily samples, and were therefore quite reliable.

As regards the removal of colloids in the activated sludge process he thought that the condition of the resulting sludge clearly indicated that a very large percentage of them had been destroyed in it.

It was impossible to say what the future of sewage treatment would be, but he thought it was quite likely that, so far as the sludge was concerned, centrifuges would play an important part in it.

3rd April, 1916.

PERCY GRIFFITH, M.INST.C.E., PRESIDENT,
IN THE CHAIR.

MODERN COAL AND COKE HANDLING MACHINERY:

AS USED IN THE MANUFACTURE OF GAS.

By J. E. LISTER, Wh. Ex., A.M.I.C.E., A.M.I.M.E.

(Of W. J. JENKINS & Co., LTD.)

The manufacture of gas consists generally in the distillation of coal in fireclay retorts. The gases evolved are led off, cooled and purified and then passed on to the holders for distribution to the town mains. The author does not propose, in this paper, to touch at all on the actual production and purification of the gas, which is more or less a series of chemical and physical processes, but to describe the mechanical apparatus used in handling the coal before its carbonization, and the resultant coke, which is the material left in the retorts after the gases are driven off.

The amount of gas produced per ton of coal varies from 10,000 to 15,000 cubic feet or more, according to the nature of the coal and the candle power required, and in the larger towns the quantity of material to be dealt with is very great, while the problem of handling it economically becomes a serious matter. To handle this coal and the resultant coke entirely by hand would cost for labour approximately 2s. 6d. per ton, but by the introduction of modern machinery this figure may be reduced to 9d. per ton, or, if conditions are suitable, to as low a figure as 6d. To obtain such results the plant must be so designed as to require the minimum of attention, and the question of upkeep must not be lost sight of, or the saving of labour will be considerably discounted by the repair bill. In a properly designed plant the annual amount required for the upkeep of the machinery should not greatly exceed 3d. or 4d. per ton, taken over a period of several years.

In the majority of cases the coal is carbonized in D section retorts. These may be only 9 ft. or 10 ft. long (known as "stop-end" or "single" retorts), or 20 ft. to 22 ft. long ("throughs"), the section varying from 20 in. × 15 in. to 26 in. × 18 in. in the most recent installations. The old method of working, which is still extensively used in the smaller works, was to charge the retorts by hand, putting charges of 3 or 4 cwts.

into the single retort. It requires considerable skill on the part of the stoker to put in regular and level charges, and unless this is done the coal is burnt off unevenly and the results are poor. It is becoming increasingly difficult to get men who can, or will, do this arduous work, and the use of machinery for introducing the coal into the retort is, in consequence, extending into the smaller works, and more modern plants are replacing the older and less efficient arrangements in the larger works.

The first improvement over the shovel was the scoop charging machine, in which a long scoop is filled with coal, raised to the required height by suitable gearing, run into the retort, and then turned over, so that the coal is deposited on the floor, or bottom, of the retort. The coke is withdrawn by means of a manual rake. In the later "West" machines these operations are usually effected mechanically by means of compressed air motors or rope drives, and many works have been equipped with machines of this type. The compressed air is led to the machine by means of flexible pipes coiled round a compensating drum, which allows them to pay out or in as the machines travel along the retort house.

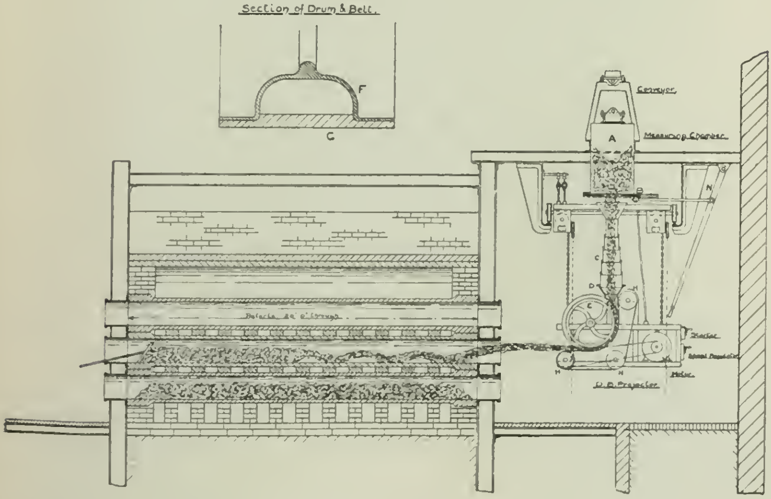
The great drawback to scoop machines is that they can only charge short retorts, so in the case of ordinary 20 ft. through settings, machines must be arranged on both sides of the bench, thus doubling the initial cost and the number of machines that have to be maintained. A further disadvantage is that space must be left over the top of the charge in order that the scoop may turn over and be withdrawn from the retort, so that the full capacity of the retort cannot be utilised. Rakes are used to withdraw the coke, one on each side of a "through" bench and each dealing with half the retort. These rakes are operated either by hand or by power in a similar way to the charging machines.

A machine on somewhat similar lines is built by Sir William Arrol & Co., and known as the Arrol-Foulis machine. It is usually operated by hydraulic power, flexible connections being provided for conveying the pressure water from the mains to the machine. In this case the discharger takes the form of a hydraulic ram, with a suitable head shaped to fit the retort. One ram only is required on one side of the bench, though charging machines are still required on both sides.

A little later machines were introduced specially to suit "through" retorts and to charge them from one end only. One of the best known of these machines was due to the ingenuity of Mr. De Brouwer, the late gas engineer of Bruges, and it was the introduction and development of this machine in this country that led to the great improvements in the methods of carbonization now in general use in the larger gasworks.

About the same time Mr. Fiddes, of Bristol, introduced a modification of the scoop idea, in which the coal is pushed into the retort in a kind of divided trough, the plates forming the sections being hinged so that after depositing the coal in the retort they can draw back over the top of the charge. The trough is made in sections which coil up round a drum when drawn back out of the retort and can be made of sufficient length to deal with through retorts from end to end. The front end of the trough forms a ram head for pushing out the coke, so that pushing and charging form one operation. These machines work well, but cannot without difficulty vary the amount of coal put into the retort, and they must leave sufficient space for the trough plates to draw back over the top of the charge A further modification of this machine has recently been introduced with the object of filling up the retorts as far as required. Messrs. Wests' Gas Improvement Company have also brought out a modification of their machines in which the charging and discharging form one operation.

The De Brouwer machine (known usually as the D.B.) travels along one side of the retort bench and the coal is projected or thrown into the retort by giving it the necessary velocity to suit the length of the retort and the thickness of charge required. Fig. 1 shows, diagrammatically, the general arrangement of a D.B. projector, with its accompanying storage



D.B. Projector Charging Machine.

Fig. 1.

hoppers and conveyor. The projector consists of a built up steel frame carrying a large grooved drum E. and three broad guide pulleys H H H, one of which is adjustable for regulating the tension of the endless belt K. The three guide pulleys (H) are arranged on the inside of the belt and are so placed that the belt is made to take about a quarter turn round the grooved drum, bearing on the two flat flanges and causing the drum to revolve at the same speed as the belt. The grooved pulley is usually made about 3 ft. 3 in. diameter by 15 in. wide, the groove being 8 in. wide by 3½ in. to 4½ in. deep according to the class of coal with which it has to deal. The motor used for driving the belt is usually an ordinary shunt wound variable speed machine of 4 to 6 B.H.P., with a speed variation of 750 to 1,500 r.p.m., but compressed air motors and rope drives are also used where the conditions are suitable, and equally good results can be obtained with them.

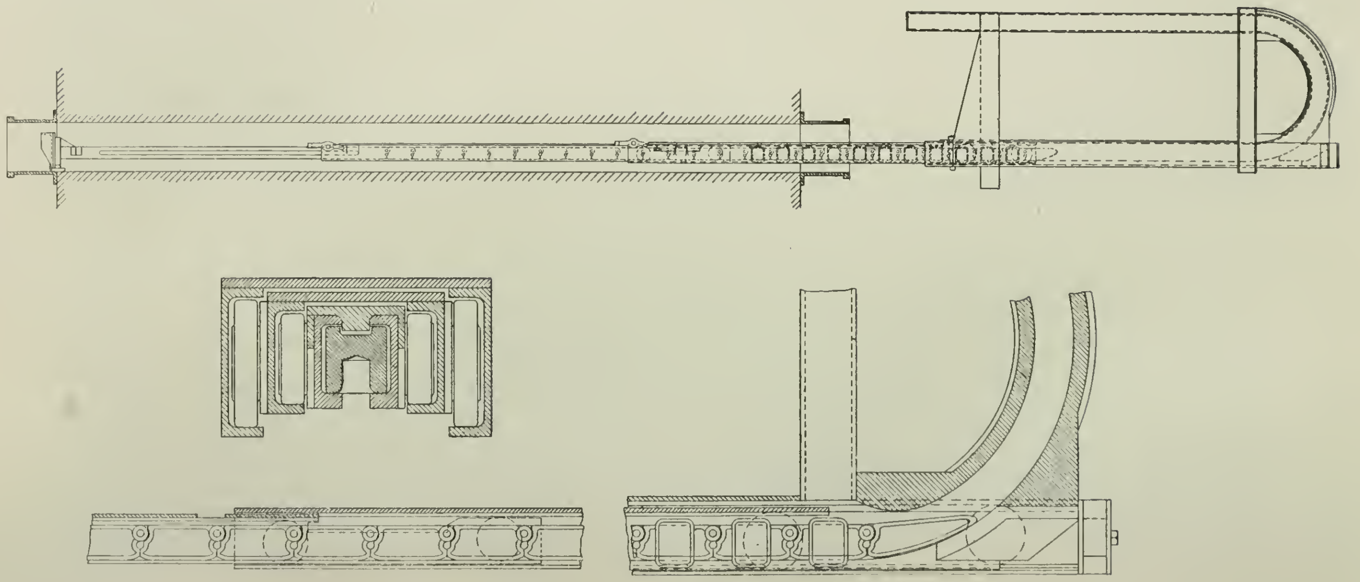
In the diagram A. is a small hopper or measuring chamber into which the coal is fed by a conveyor running along the top. Doors are arranged in the bottom of the hopper opposite each vertical tier of retorts, so that the coal can pass directly from the hopper through the shoot C. to the machine. The shoot C. is made telescopic so as automatically to adjust itself as the machine is raised or lowered to the various retorts. At F. is shown a section of the grooved drum with the belt G., showing the space into which the coal is guided by the tundish D.

The operation of charging is as follows: Assuming that the overhead hopper is already full, the operator first starts the motor and moves the handle of his speed regulating rheostat into the position necessary for giving the projector belt the required speed. This speed varies according to the length of the retort, the class of coal used and the thickness of charge required, and must first be found by trial. With ordinary broken coal and charges of say 9 cwt. in a 22 in. × 16 in. × 20 ft. 0 in. retort the belt speed should be about 2,300 ft. per minute, but if the retorts are to be charged full, more speed will be necessary, up to about 2,700 ft. per minute. The hopper door is then opened and the coal falls through the telescopic shoot and tundish into the space between the belt and the pulley. The centrifugal force exerted on the coal as the belt passes round the circumference of the grooved drum keeps it in contact with the belt, and prevents slipping, so that the velocity of the coal becomes the same as that of the belt.

As the coal reaches the front pulley, the belt is suddenly deflected round the pulley, but the momentum of the coal keeps it travelling forward into the retort in a continuous stream. Sufficient velocity is imparted to the coal to cause it to travel right through the retort until it reaches the stop and then pile up to the required depth. The distance through which the coal travels is gradually decreased as the operation of charging proceeds, so if the initial velocity were maintained right through the operation of charging, less energy would be required to overcome the sliding friction and the coal would, therefore, pile up to a greater thickness, the nearer the charge approached the machine. The charging would, consequently, be very irregular. This is prevented by reducing the speed of the belt as the operation proceeds. This reduction of speed is usually effected by regulating the speed of the motor, but with rope driven machines other means are adopted, as in this case the rope must run at a constant speed. The whole operation of charging takes from 20 to 30 seconds, according to the amount of coal put into the retort, and by varying the initial speed of the belt any desired thickness of charge may be put in, or the retorts can be packed practically full from end to end, if desired.

These early machines were suspended from an overhead carriage and traversed along by hand, but as this was a somewhat slow process the later machines are arranged in a travelling carriage or frame and driven by power. It was soon found that the use of heavier charges than those previously employed gave better results, both as regards make of gas per ton of coal and the quality of the coke produced, but so long as the rake was used, it was necessary to leave sufficient space over the charge in the retort to allow the rake head to be introduced. This led to the introduction of a ram, or pusher, suitable for pushing out the whole of the coke from one end of the retort.

The ram is built up in several lengths, which telescope one inside the other, in order to reduce as much as possible the clear space required between the retort bench and the wall. The first or outer length of this ram consists of a solid bar, in which rack teeth are cut in the underside, and in order to enable this to be driven right through the retort, a number of links with teeth cast in, are jointed on to the tail end of the bar. This forms a long rack which, by the peculiar construction of the links, is flexible in one direction only ; that is, the links will coil up and return through the curved guide path at the back end of the machine, but when the end links are rigidly held the chain is stiff in the other direction and will extend out as a solid bar inside the box-shaped guiding lengths. This is shown in Fig. 2. The box lengths, which are used mainly to prevent side thrust on the retort walls, have been discarded in the latest design. When there is ample room between the bench and wall of the retort house the telescopic ram is made in two lengths only, but where room is limited the ram is built up of three telescopic sections. A somewhat similar machine is built by West's Gas Improvement Company.



ARRANGEMENT OF JENKINS' D.B. PUSHER RAM.

FIG. 2.

Both projector and pusher are fitted with a safety gear to prevent overwinding when hoisting or lowering the machine. This consists of a tappet gear which is so arranged that should the machine be hoisted or lowered too far, an electric cut-out is operated and the circuit broken. Another safety gear is also fitted on the pusher, which cuts off the current and stops the motor automatically at the two ends of the stroke of the ram. This consists of a differential gear driven by a roller chain from the pusher motor, the differential gear being so proportioned that the outer gear makes about three-quarters of a revolution during the complete stroke of the ram. This outer gear carries two tappets, which operate the controller handle through a quadrant and bring the controllers to the " off " position just before the completion of the stroke. The arrangement of the tappet gear prevents the operator from moving the controller back to its last position, but enables him only to reverse the motor. Spring returns on the controllers ensure them returning fully to the " off " position when moved by the tappets.

Both travelling and hoisting movements are controlled by one motor through the gear box, either motion being put into gear by means of a spring lock hand lever conveniently situated at the side of the driver's platform. The hoisting gear operates through a worm and wheel and is consequently self-supporting. For small works it is often convenient to have the charger and discharger arranged in the same travelling frame, so that they can conveniently be operated by one man.

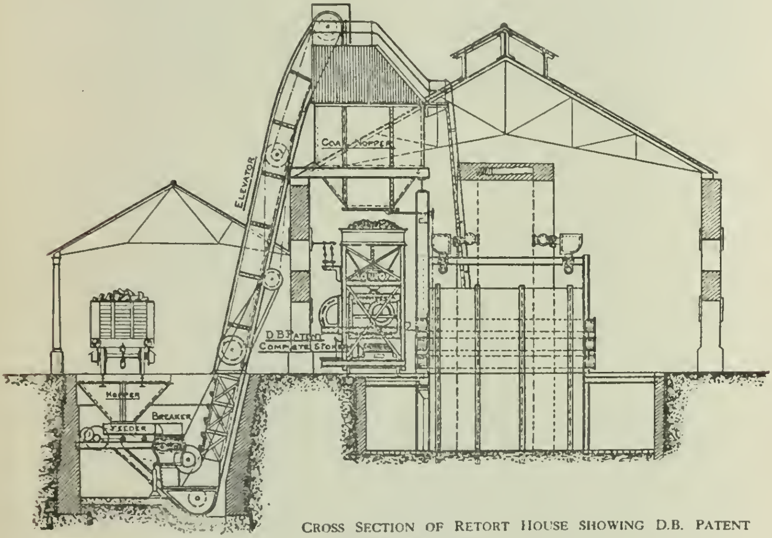
In many recent cases the charging machines and complete stokers (or combined charging and discharging machines) have been fitted with weighing chambers for regulating the charges put into the retorts. A large dial and pointer, arranged in front of the operator's platform, show the weight of coal run into the chamber from the overhead hopper, and also act as a guide to the man when he is regulating the speed of the motor, and thus greatly facilitate the putting in of level and uniform charges. The chambers are made with capacities of 12, 15, or 20 cwts., according to the size of the retorts. In some works charges of 15 and 16 cwts. are being regularly put in by the D.B. machines.

Coal Handling Plants.—The foregoing remarks will have given some idea of the introduction and development of machinery for charging and discharging retorts and it is mainly on account of the use of these machines that improved methods of dealing with the coal and coke are required. The coal must be elevated into overhead hoppers from which the travelling machine can take its supplies and the methods of charging used in the various types of machines all require the large lumps of coal to be broken to a suitable size. This is most conveniently done before elevating into the storage hoppers, so that coal brought into the works by rail or cart is usually fed through a breaker and down suitable shoots to the elevator boot. If the coal comes in by rail, the labour required for unloading the wagons is generally an important item, costing perhaps 2½d. to 3d. per ton, and in many cases mechanical wagon tippers can be profitably installed, provided wagons fitted with end delivery doors can be obtained regularly. One man can then deal with large quantities of coal without difficulty.

The tipper is fixed between the railway lines close to the receiving hopper which supplies the coal-breaking plant, so that when the wagon is lifted the coal runs out through the end door directly into the hopper. The lifting frame of the tipper is guided in steel uprights and engages with the rear axle of the wagon. It is raised by hoisting chains operated through worm gearing fixed on one of the side plates, the gear running in an oil bath and being driven by a belt from the engine driving the coal plant or by an independent motor. With this arrangement the unloading can be done at a cost of about ¾d. per ton of coal. An additional saving can frequently be obtained by using a capstan for moving the wagons to and from the tipper.

The coal breaking plant is usually arranged in a pit below ground level, though occasionally local conditions make it preferable to keep it above ground. The coal is delivered into a hopper, under which is arranged a feeder. This regulates the supply to the breaker and prevents choking. A screen is placed between feeder and breaker, with a shoot underneath, so that the small coal passes directly to the lower hopper or elevator boot, without having to pass through the breaker. The coal breakers must be of heavy construction as they have to crush large lumps of coal or cannel down to a small size (about 2 in. cubes or less) in order to suit the charging machinery. They are usually constructed with heavy cast-iron frames, with gearing and claws of cast steel, though in some cases steel plate frames are used. The average power taken when crushing lumps of hard coal is approximately 8 B.H.P., but to avoid pulling up the engine or driving motor on account of the sudden fluctuations of load, the driving pulley is made with a heavy flywheel rim.

The complete arrangement of a typical coal handling plant, as recently erected at many gasworks, is shown in Fig. 3. The coal breaking plant is similar to that just described, with an elevator of 25 tons per hour capacity and a central overhead storage bunker holding about 40 tons of coal. The elevator is of the ordinary bucket type with malleable iron buckets bolted to a manganese steel chain. Cast-iron skidders are fixed to the buckets and these run on cast-iron wearing strips bolted to the elevator framework. The Author always recommends manganese steel chains for elevators in preference to the more usual malleable iron, as it is very little more expensive in first cost and the risk of breakage of the chain is practically eliminated. An elevator of this type with buckets 12 in. wide by 9 in. deep will raise about 25 tons of coal per hour when running at 120 ft. per minute, and about 5 H.P. should be allowed for a lift of 70 ft. to 80 ft.

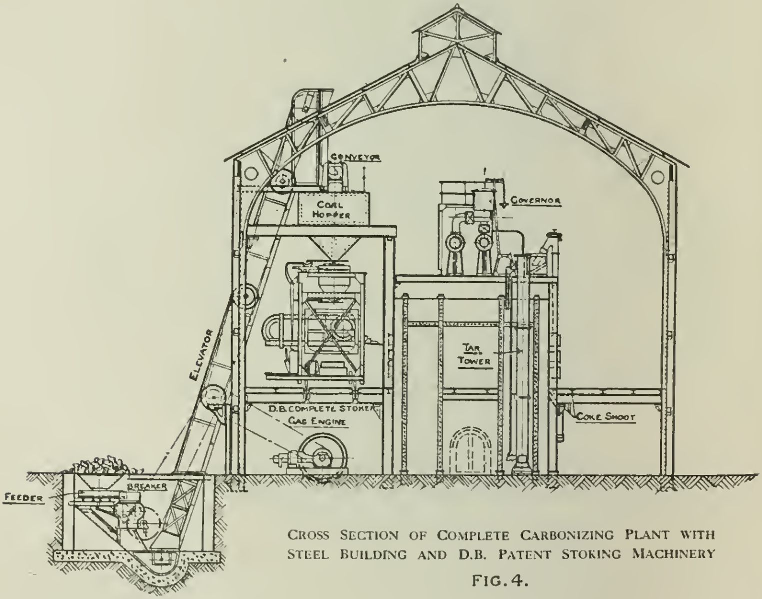


CROSS SECTION OF RETORT HOUSE SHOWING D.B. PATENT STOKING MACHINES & COAL HANDLING PLANT

FIG. 3.

The next illustration (Fig. 4) shows a complete plant which together with the steel-framed retort house, was recently supplied to the Osaka (Japan) Gas Company. The structure had to be made specially strong on account of the great storms to which the district is subject. In this case the combined charging and discharging machine is fitted with a weighing chamber, and a hopper holding a 24 hours supply of coal is arranged in front of each bed of retorts. The elevator, which is of the usual enclosed type, with malleable iron buckets carried on a manganese steel chain, delivers the coal on to a push-bar conveyor which distributes it into the various hoppers. This arrangement, though more expensive than the central hopper plant in first cost, is rather more economical in working, as with the larger capacity of the storage hoppers, it is only necessary for the coal plant to be worked during the daylight shift.

The hopper conveyor, instead of being of the push bar type as shown, is frequently of the ordinary push plate type, or may be a band conveyor or a gravity bucket arrangement. Local conditions usually determine which type shall be installed. Scraper or push plate conveyors are very convenient for dealing with small coal, owing to the ease with which the point of discharge can be altered, while by only partly opening some of the doors the coal can be made to discharge at two or three points simultaneously. In the smaller sizes the crossbars carrying the push plates are supported by skidders running on guides on the side of the trough. Larger sizes are generally made with rollers instead of skidders, as this arrangement materially reduces the power required.



CROSS SECTION OF COMPLETE CARBONIZING PLANT WITH STEEL BUILDING AND D.B. PATENT STOKING MACHINERY

FIG. 4.

These conveyors work at speeds between 100 and 200 ft. per minute and vary in sizes up to 24 in. wide. The capacity of a 24 in. conveyor with scrapers pitched 2 ft. apart and running at 100 ft. per minute would be approximately 150 tons per hour. This is for a horizontal conveyor. Placing the conveyor on the slope entails a reduction in carrying capacity of about 16 per cent. for each 10° of inclination. The following table gives the approximate capacity of scraper conveyors in tons per hour when handllng coal and running at 100 ft. per minute, for various sizes and spacing of scrapers :—

Size of Scraper.	Distance apart of Scrapers.			
	16 in.	18 in.	24 in.	
4 in. × 10 in. ...	30	27	20	Capacity in tons of coal per hour.
5 in. × 12 in. ...	45	40	30	
6 in. × 18 in. ...	—	70	50	
8 in. × 20 in. ...	—	—	90	
10 in. × 24 in. ...	—	—	150	

These figures to be reduced by 16 per cent. for each 10 per cent. of inclination.

Another type of conveyor which is very frequently used where large quantities of small coal are to be handled is that known as the gravity bucket conveyor. This consists of two strands of chain supported by rollers or skidders and carrying between them a series of buckets. The buckets swing freely from spindles fixed to the two chains and hang vertically no matter what the direction of the chains. This type of conveyor can, therefore, be used for carrying material both vertically and horizontally and by means of suitable tripping gear the buckets can be made to discharge at any required point of their horizontal travel. The trip gear consists of a casting attached in a convenient position on the side of the bucket, this casting being struck by a lever or other arrangement, and the bucket consequently tripped at the desired point. A typical arrangement is shown in Fig. 5.

The buckets are generally filled by an automatic feeder which brings a series of openings or pockets containing a suitable amount of coal over each bucket in turn. This prevents spilling of the coal and ensures the buckets being evenly filled. The following table gives the power required for various sizes of gravity bucket conveyors. An addition of 5 per cent. should be made to the power for each turn or change of direction :—

Size of buckets ...	in. in. 12 × 12		in. in. 24 × 15		in. in. 36 × 20	
Spacing	18″	36″	18″	36″	18″	36″
H.P. for each 10 ft. vertical lift ...	0·46	0·23	1·35	0·67	3·8	1·9
H.P. for each 100 ft. per hour empty ...	1·2	0·9	1·7	1·3	2·4	1·6
H.P. for each 100 ft. per hour with coal	3·2	1·9	7·4	4·2	18	9·4

WILSON GLASGOW VERTICAL RETORTS. CONTINUOUS INTERMITTENT SYSTEM.

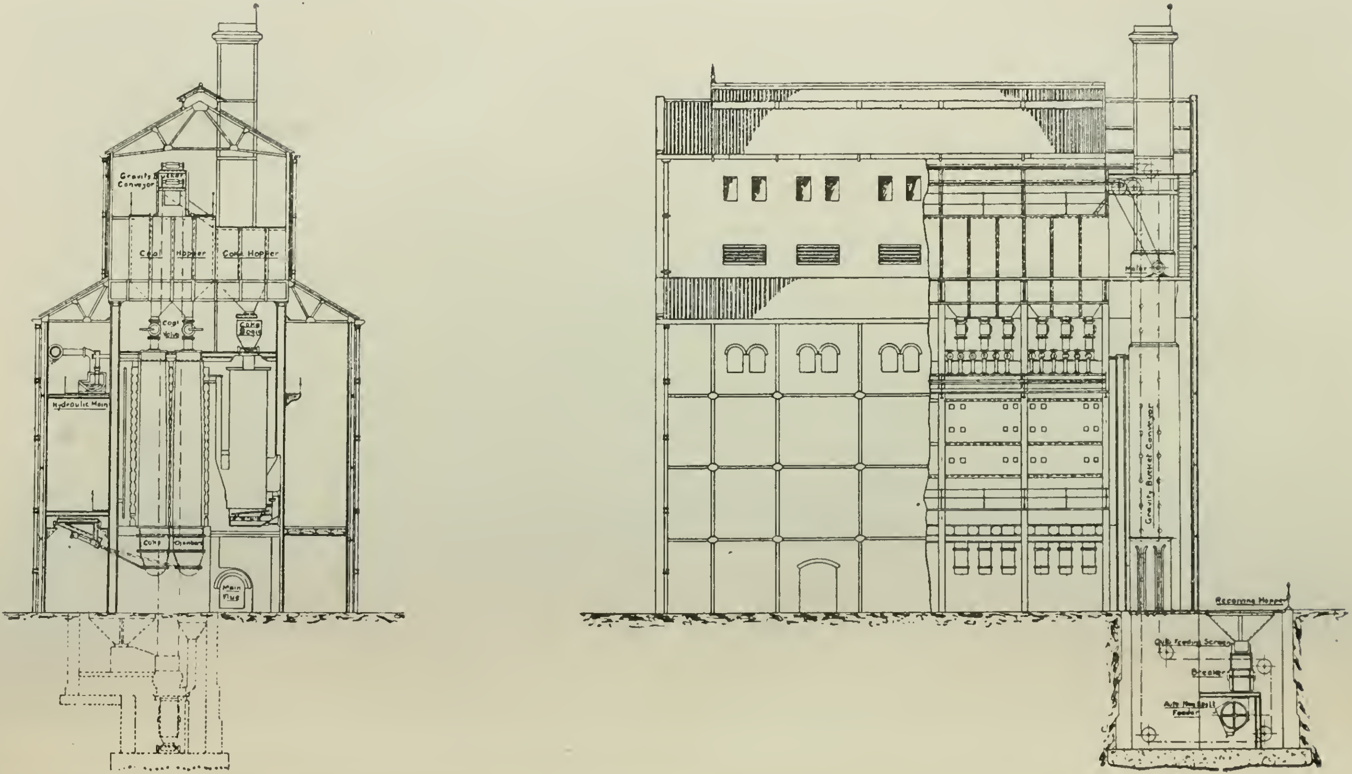


FIG 5.

Band conveyors are frequently used for delivering coal into stores, as, by means of a suitable travelling throw-off carriage, they can be arranged to deliver at any point along the conveyor and so fill up the stores from end to end. They require very little power in proportion to the amount of material carried, and they are smooth and noiseless in working. Ordinary cotton conveyor belting is very generally used, but a built up belt of cotton duck and rubber gives by far the best results. The Author knows of one installation where a belt of this type has dealt with something in the neighbourhood of 200,000 or 300,000 tons of coal, and the latest information he had, some five or six months ago, was that the one face of the belt was just done for and it was now to be turned over and the other side used. These belts are naturally much more expensive than those of plain cotton, but for installations where first cost is not the most important item, they are well worth the extra cost. They are frequently made with additional plies of duck at the edges and fewer in the middle, with a corresponding extra thickness of rubber. Rubber faced belts should not, however, be used where the belt is continually subject to heat.

The belts are carried on sets of rollers arranged at short intervals along the framing. A flat belt has the longest life, other things being equal, but a very greatly increased capacity can be obtained by causing the belt to run in a troughed shape. Additional rollers are fixed at longer intervals to prevent side movement of the belt. The carrying side only is troughed and the return side flat. The angle between the rollers must not be too sharp, or the belt will very soon fail at the corners.

The end pulleys should not be less in diameter than 5 in. for every ply of the belt, *i.e.*, for a 6-ply belt the pulleys should not be less than 30 in. diameter. The working stress in the belt when loaded should not exceed 30 lb. per inch of width per ply. The following table gives the effective cross section of the layer of material carried by belts of various sizes when running flat and when troughed, and shows the great increase in carrying capacity to be obtained by troughing the belt :—

Width of belt. Inches.	Effective cross section of material. In square feet.	
	Flat Belts.	Troughed Belts.
18	0·08	0·19
24	0·16	0·34
30	0·27	0·55
36	0·4	0·8

The power required for conveyors of the usual construction is given approximately by the formula—

$$\text{H.P.} = \frac{W_B\,(0\cdot15L) + W_M\,(H + 0\cdot07L)}{33{,}000}$$

Add 5% for each tripper,

where W_B = weight in lb. of belt (total).
W_M = ,, material per min.
L = length in feet of conveyor.
H = height in feet of lift.

One of the principal London gas companies has recently installed a band conveyor plant for delivering coal from a pontoon or wharf fixed in the Thames to a large bunker arranged over the end of a retort house. The bunker holds 600 tons, and the conveyor, which can deliver at various intermediate points, has a capacity of 140 tons per hour. All the coal on its way to the bunker passes through a weighing machine, so that a constant check can be kept of the amount of coal carbonized. The conveyor is divided into three sections, and the total length is 465ft. The width of the belt is 2ft. 6in., and the speed 190ft. per minute. The plant is driven by a gas engine of about 30 H.P.

In some cases the charging machines are themselves fitted with elevators and hoppers holding 7 tons of coal, and there is no overhead storage plant. Instead, openings are left in the wall between the retort house and the coal store and the elevators on the machines can be screwed back into these openings in order to pick up the coal. Elevator machines are most suitable for cases where the coal comes into the works in large quantities at a time, as by boat, and the coal store can be arranged along the retort house. The elevators can deal with the coal at the rate of 60 tons per hour, so that the time required to fill the hopper is only six or seven minutes, and the machine can then charge about 10 retorts before requiring a fresh supply.

When the coal comes directly alongside the works in ships or barges the vessels are generally unloaded by means of cranes and grabs or by an elevator arrangement. This consists of a bucket elevator, which is carried on a cantilever extending out over the river or canal. The elevator slides in the framework, and can be raised and lowered by suitable gearing to suit the height of the water and the level of the coal in the ship or barge. The coal is delivered by the elevator on to a conveyor which distributes it into the stores.

Coke Handling Plants.—So far we have dealt only with the question of handling the coal, but as each ton of coal produces 13 to 14 cwt. of coke, the coke handling question is also very important. Coke is a difficult material with which to deal, owing to its hard and gritty nature, and unless the apparatus used for handling it is suitably designed, the wear and tear is very great. In addition, the coke is red hot as it leaves the retort, and must be quenched and cooled to the proper degree before being stored or it will take fire in the storage hopper or coke yard. At the same time it must not be over-quenched, or customers will naturally complain at being supplied with water at the price of coke. With suitable arrangements and proper care on the part of the men, the amount of moisture can be kept down to 3 or 4 per cent. The author has known cases where, on account of careless handling, the percentage of moisture has gone up to 10 or even 15 per cent.

There are two principal methods of dealing mechanically with hot coke : (1) by means of conveyors and (2) by means of transporters or telphers. Each method has its advantages, and the question as to which shall be adopted must be decided entirely by the local conditions. In many cases a combination of the two is the ideal arrangement, a conveyor being used inside the retort house and a telpher outside in the coke yard.

The chief advantages of a conveyor are that it is continuous in action, and therefore does not restrict the speed of the stoking machinery, and when once started to work it is practically automatic in action, and does not require a man in constant attention. One objection that is frequently advanced to the use of conveyors is the breakage of coke said to be caused by them, but if proper attention be given to the design of the plant, the breakage can be reduced to a very small amount.

The principal advantages of a telpher plant are the amount of ground that can be covered without an excessive expenditure and the small amount of handling received by the coke, with a corresponding decrease in the production of breeze. At the same time, with a plant of this type, the speed of the stoking machinery is regulated by the time taken by the transporter to run out with a load, deposit it at the required spot, and return for a fresh charge, and in many cases this results in a considerable delay in the working. This delay may not be material in a small plant, but in a large one it is an important consideration. A man is required constantly on each telpher, which increases the labour cost, but the cost of upkeep is light. A telpher plant will cost approximately £450 for the transporter itself and £3 to £4 per foot run for the track, the cost depending mainly on the number of curves and the height of the track above ground level and the load to be carried.

A conveying plant will probably cost from £4 to £6 per foot run, the lower figure being the cost of the portion inside the retort house, where the trough and return path can be supported from the floor structure, and the higher figure including supporting trestles or other structure for carrying the conveyor at a suitable height above the ground in the coke yard. As mentioned above, the ideal arrangement is frequently a combination of the two methods. By arranging a conveyor in the retort house, with a hopper at the end of the house, capable of holding all the coke produced in one draw, the stoking machinery can work at its full speed, and the telpher can distribute the coke to the required points between the rounds, when there is a man available who would perhaps be otherwise disengaged.

One of the best known hot coke conveyors was also the invention of Mr. De Brouwer. One firm alone in this country has made over 7 miles, while considerable lengths have also been made by Continental firms. Most of the successful hot coke conveyors now in use are of this type or more or less close copies of it. The trough is lined with renewable cast iron bottom plates and side angles, and is made watertight, so that water may be run into the trough or sprayed on to the coke for quenching purposes. As the red hot coke leaves the retorts it is directed into the trough by a deflecting plate or shoot, and is drawn forward by the chain.

The chain is built up of steel stampings, consisting alternately of blocks and side links, held together by steel rivets. At intervals of about 2ft. the two strands of chain are joined together by a crossbar, which keeps the links the correct distance apart and drags or pushes the coke along the trough. The side links are so formed that the whole of the wear is taken up by the bosses working in the blocks, none of the wear coming on the rivets, which merely hold the links together. A chain of this type will deal with 50,000 or 60,000 tons of coke or more during its working life. The chains are protected from coke falling into them by cover angles or tees bolted to the sides of the trough. These angles or tees serve the additional purpose of holding down the cast iron bottom plates. The return strand of the chain is usually carried on a path formed of steel angles with cast iron wearing strips bolted on. This path may be arranged under the retort house floor, or carried on brackets overhead.

The conveyors are arranged horizontally in front of the bench, and at the end of the retort house are frequently carried up at an angle of about 30° or 35° to give sufficient headroom for a considerable amount of coke to be stored in the yard or in suitable storage hoppers. By slightly altering the shape of the crossbars conveyors can be arranged at slopes up to 45°. This type of conveyor, suitably modified, is also excellent as a coal conveyor, the special construction of the chain making the wear negligible, even after several years' work. The working speed of the chain is about 40 to 50ft. per minute, and the power required 1 H.P. for each 30ft. of horizontal conveyor and about 1 H.P. for each 20ft. on the incline, depending, of course, on the actual slope.

Another type of conveyor which is considered by some engineers to be the best for coke, ashes and other sharp and gritty materials is the tray or carrying conveyor. This consists of a series of overlapping steel trays fixed to a steel chain running in the conveyor trough. The material is carried quietly along without friction, and in this respect the tray conveyor is good for brittle or friable materials, but in the author's experience this type of conveyor, when used for coke, at any rate, is more expensive in upkeep than those of the D.B. type, and if the latter are properly designed and constructed the amount of breakage of the coke is not appreciably different.

A somewhat novel arrangement has recently been adopted in one or two installations to enable a large amount of storage space to be covered by the conveyors, with special arrangements for filling railway wagons or dumping the coke on to the ground without breakage. The retort house portion of the plant is arranged as usual, with an inclined portion outside the house, delivering on to a long yard conveyor. On one or both sides of this yard conveyor a track is arranged on which runs a travelling cross conveyor. These cross conveyors take their supply of coke from doors and shoots in the yard conveyor trough, and are hinged at the inner ends, the outer ends being slung on chains by which they can be raised or lowered. The lowering conveyors enable the coke to be placed gently on the ground instead of dropping it from a considerable height, and as the heap increases, the conveyors are raised, thus greatly increasing the storage capacity of the ground. Instead of depositing the coke on the heap, the doors may be closed, the two shoots at the lower end opened, and railway wagons filled at any point along the sidings.

Telpher Plants.—A telpher or transporter plant is most useful where the coke or other material can be dealt with intermittently, and where a large area of ground is to be covered and the material stacked to a considerable height.

The telpher itself consists of a carriage carried on two bogies which run either on the bottom flange of the track girder or on a single rail rivetted to the top flange. The latter arrangement is the better when there are curves to be negotiated, but is somewhat more expensive, as the construction of the track and supports is not quite so simple. The machine is provided with a cabin, in which the attendant sits, and is driven by two electric motors, one for travelling and the other for hoisting. For loads of, say, 1 ton, the travelling motor is of about 7 H.P., and the hoisting motor 11 H.P. Both motors work through cut spur gearing or roller chains. The two bogies, from which the carriage is supported are pivoted to allow the machine to traverse curves of small radius.

TELPHER COAL AND ASH-HANDLING PLANT AT HACKNEY GENERATING-STATION.

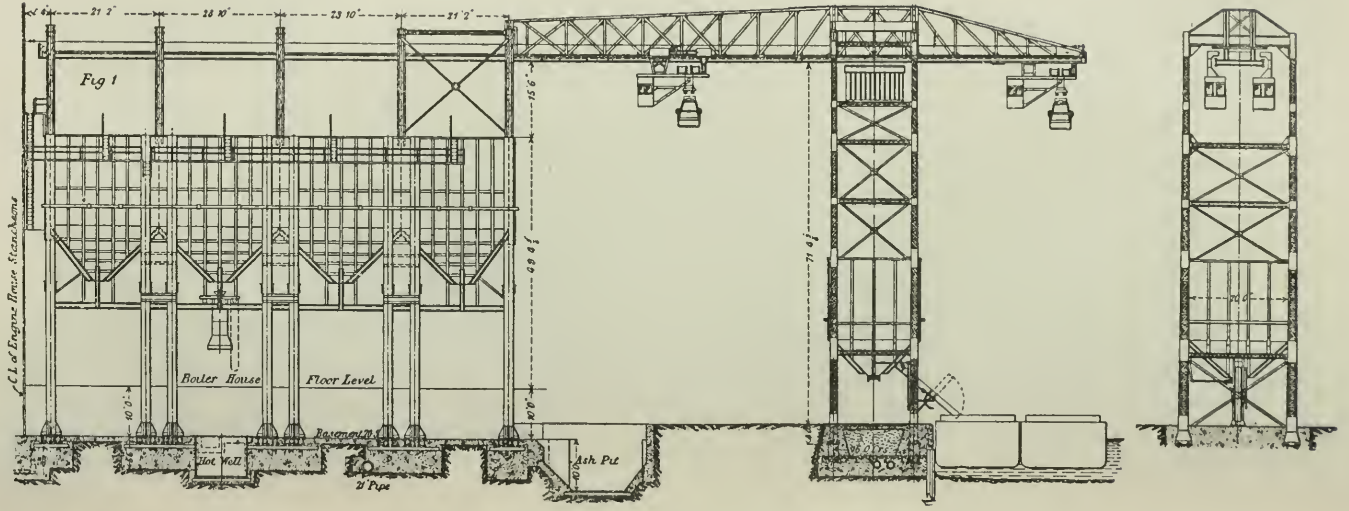


FIG. 6.

Fig. 6 shows a large telpher plant for handling coal and ashes recently erected in London. The bunkers hold 1,300 tons of coal, and the plant can unload barges at the rate of 40 tons per hour. There is a double track on which two machines can work simultaneously, and weighing machines are embodied in the track girders so that the actual weight of coal delivered by the barges is checked as it enters the works. In this case, as the telpher has to deal with a total load, including the grab, of nearly 3 tons, the hoisting motor is of 25 B.H.P., and the travelling motor of 12 H.P. The hoisting speed is 80ft. per minute, and travelling 450ft.

In the foregoing remarks the author has dealt principally with the methods of handling coal and coke in connection with horizontal retort installations. With the newer methods of carbonization in vertical retorts and coke ovens or chamber ovens the problems are essentially the same, but under slightly different conditions, and the type of machinery employed varies accordingly.

Fig. 5 shows the general arrangement of a vertical retort installation, in which the coal, after being crushed in the usual manner, is elevated by means of a gravity bucket conveyor. This is carried forward over the hoppers, and tripping gear is arranged so that any compartment may be filled at will. The coke may be removed either in small bogies or by means of a conveyor arranged under the setting. The coal conveyor or elevator is frequently used also for elevating the coke required for the furnace, a separate shoot being employed for feeding the coke to the buckets. In other cases the coke bogies are raised bodily in a hoist to the top of the setting, or the hoist is added as a stand-by in case of any breakdown of the elevator.

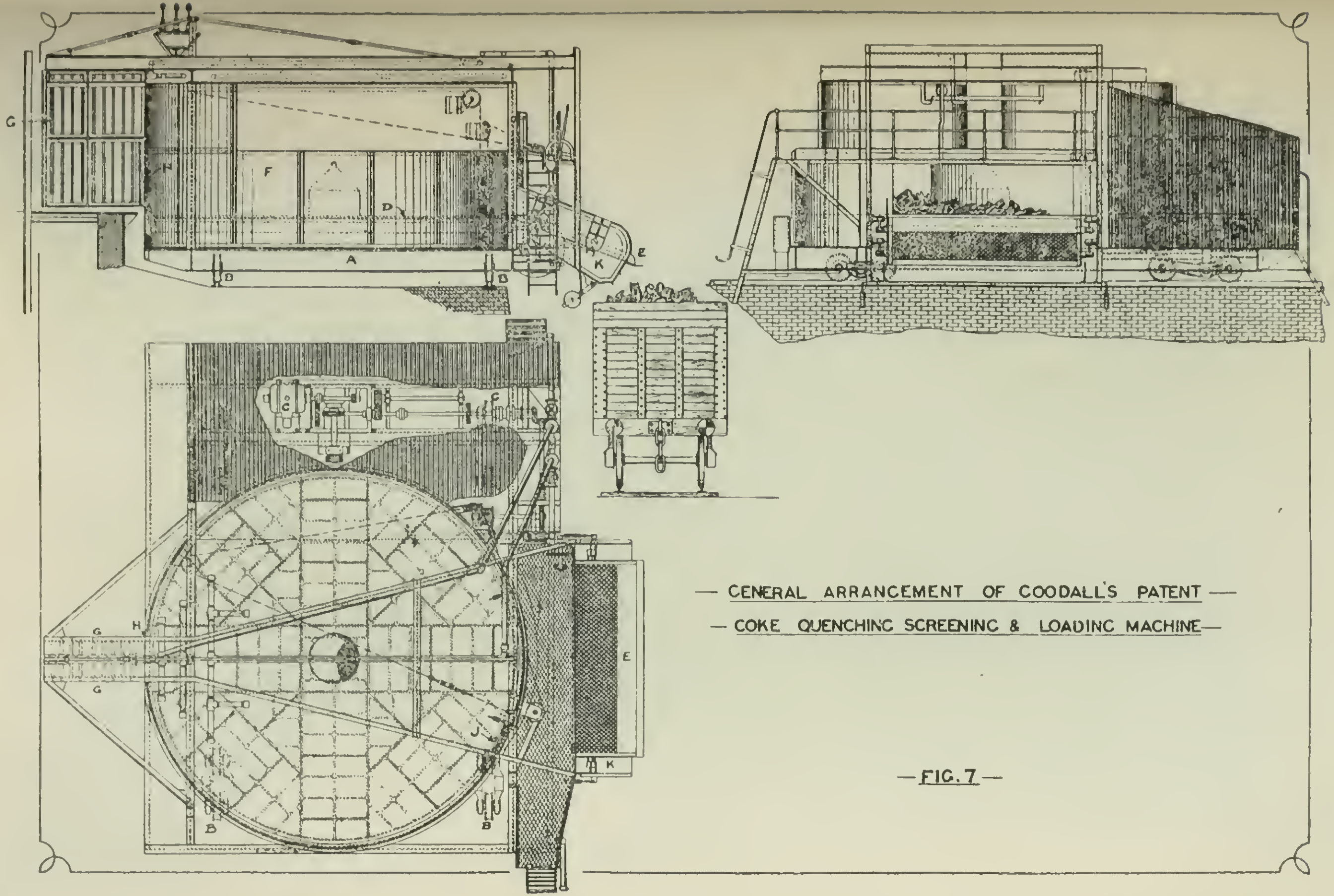
Coke Oven Machinery.—Until recently the manufacture of gas and the manufacture of furnace coke have been two entirely different businesses. In gas manufacture the coke is produced as a by-product, while in coke making it is the gas which is the minor product, and in many cases is still allowed to go to waste, and it is only in the last year or two that the two processes have been combined on a gasworks in this country in the large plant installed at the Saltley Works of the Birmingham Gas Department. In Middlesbrough also, arrangements have been made to utilise some of the gas produced at the local coke ovens of Sir Bernard Samuelson & Co. by mixing it with the gas produced at the gasworks and delivering it through the town mains in the usual way. These two experiments have opened up a new field for the gas undertakings and collieries of this country, and it will perhaps be interesting to describe some of the special types of machines used for dealing with the heavy charges used in coke ovens.

With many coals it is considered advisable to compress the crushed coal into a solid mass before placing it in the oven, in order to make a dense homogeneous coke. To effect this the wet crushed coal is fed into a box of approximately the same section as the oven, say, 8ft. to 9ft. high by 18in. wide by 33ft. long, over which is fixed a stamper. This consists of a small travelling carriage carrying a pair of stamps, which are alternately lifted and allowed to fall as the carriage travels to and fro over the top of the box. The bottom of the box consists of a movable plate or peel fitted with a rack on the underside, by means of which it can be driven forward into the oven, carrying with it the cake of coal. When the cake is fully in the oven, a plate is wedged behind it to prevent movement and the peel withdrawn. The charge, after coking, is pushed out by means of a heavy ram, driven through steel gearing by a steam engine or motor, and frequently carried on the same framework as the charger.

In the case of coal which does not require stamping, it is introduced into the ovens through openings in the top or crown, and the charge is levelled off and slightly compressed by means of a reciprocating bar introduced through a small opening left in one of the doors. This levelling bar is usually carried on the same frame as the ram, and driven by the same motor through suitable gearing. In one type of machine the levelling bar is driven by wire ropes through a reversing clutch actuated by tappets on the bar, so that when once started it automatically reverses itself at each end of its stroke. The coke pushed out by the ram usually falls on to a sloping table or bench lined with cast-iron plates, on which it is quenched. In many cases this work and the loading of the coke into wagons is still done by hand, but recently mechanical arrangements have been adopted and are becoming more general.

Where the coke has to be loaded at a fixed point near the end of the bench a conveyor may be used. The bench is constructed with a steep slope (say 30°) down from the ovens, and a conveyor arranged along the lower edge, with gates to prevent the coke falling on to the conveyor before it is properly quenched. These conveyors are usually of the tray type, and are expensive in upkeep, while considerable shunting is required to keep a supply of empty wagons at the loading point. More recently machines have been brought out for quenching the coke, screening it and loading it into the wagons mechanically at any point along the bench.

One of these is the machine patented by Mr. A. Goodall and shown in Fig. 7. This machine consists of a large built-up underframe A, supported on wheels B, which run on rails placed along the front of the ovens in the position usually occupied by the coke bench. The underframe carries a motor and gearing C to



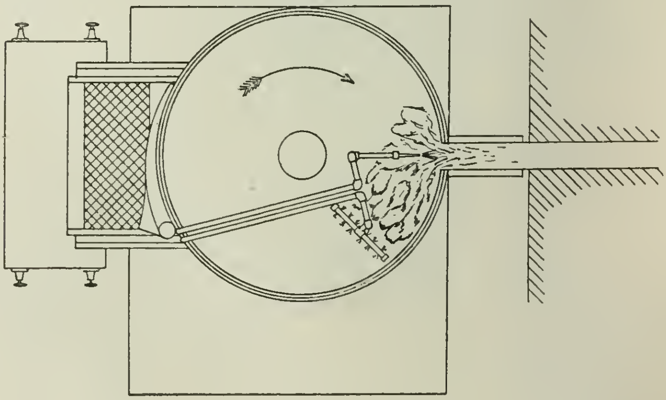
— GENERAL ARRANGEMENT OF GOODALL'S PATENT —
— COKE QUENCHING SCREENING & LOADING MACHINE —

— FIG. 7 —

propel the machine along the rails, to rotate the table D and drive the shaking screen E. The table D revolves on a pivot in a footstep bearing on the main frame, rollers also being provided round the outer edge to keep the table horizontal. The table revolves inside a shell F, constructed of steel plate and angle with cast-iron liners. Two openings are provided in this shell, one being closed by a door J and the other, which is directly facing the oven, is closed temporarily by a sliding door H. A perforated hood G is arranged between this opening and the oven, and quenching pipes are arranged round it to enable the cake of coke to be quenched as it is pushed out of the oven. When closed, the door J forms part of the shell, but when open it projects inwards, and, being fitted with plough-shaped castings on the back, it acts as a scraper for removing the coke from the revolving table. Under the doorway is arranged a jigging screen E, and the coke coming off the table falls on to the screen and passes thence properly screened into the wagon. A small hopper K under the screen receives the breeze and small coke, and can be emptied periodically. Above the revolving table is fixed a radial quenching pipe, perforated to act as a spray, and two single nozzles, one to play on to the middle and the other on to the side of the cake of coke as it falls forward on to the revolving table. In some cases the machines are fitted with mechanically operated jib cranes for lifting the oven doors.

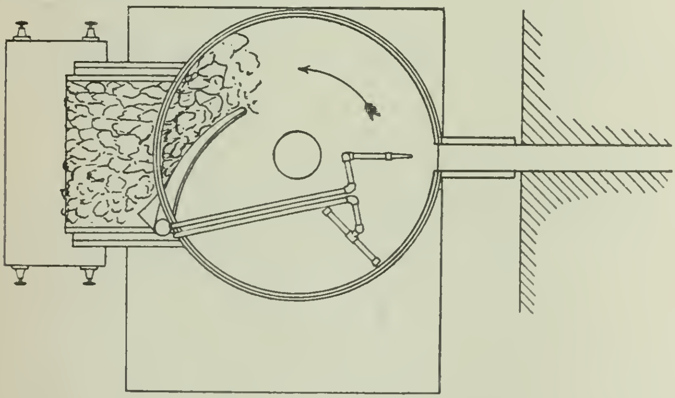
The method of working is as follows :—

The machine is run along the rails to the oven which is to be discharged, the table set in motion in a clockwise direction, and the slide door withdrawn. While the oven door is being lifted



Quenching Operation.
Fig. 8.

the water is turned on, and when the table is wetted all over the pushing is commenced. As soon as the glowing cake of coke enters the hood, the water sprays round the hood are turned on. The coke passing through the hood falls on to the table, as shown in Fig. 8, and the rotary motion of the table, combined with the continuous forward movement of the coke, lays the latter gently down on to the table. When all the coke has been pushed through the hood, the hood sprays are turned off and the door H shut. The table sprays are left on for another minute or so, and the machine moved out of the way so that the oven door may be replaced at once. The water is then turned off, and the coke allowed to steam and dry for a few minutes, the attendant quenching any red pieces with a hand nozzle. The machine is moved along to any convenient wagon, and the table started in a counter-clockwise direction. The discharging door or plough is then opened gradually, and as the table revolves the coke is pushed out over the jigging screen into the wagon. This operation is shown in Fig. 9.



SCREENING AND LOADING OPERATION.

FIG. 9.

The whole process from commencing to push to the loading of the wagon, including steaming or drying, occupies about 25 minutes, and one machine will deal with the coke from a battery of 50 ovens. Under these conditions the total labour cost for quenching, screening and loading into wagons runs out at about 2d. per ton of coke handled, as compared with 8d. per ton on the old flat benches. A motor of about 20 H.P. is ample, the average power taken when dealing with the coke from an 8 or 9 tons charge being only about 14 H.P., which works out at approximately 0·36 unit per ton of coke Where the railway truck is further than usual from the ovens a short screening conveyor is fitted instead of the jigging screen.

An automatic arrangement is fitted on this type of machine for picking up the quenching water by means of a centrifugal pump from a trough running along the bench. The trough is covered by means of hinged lids which are automatically lifted and shut as the machine travels along. This arrangement obviates the constant coupling and uncoupling of the hose and is found to be a great convenience.

There are many other machines which might have been described without exhausting the subject of coal and coke handling machinery, but this paper has already grown to an undue length, and the author would only emphasize again the necessity for the proper design of all such machinery, particularly if for handling coke, in order to keep the cost of maintenance down to the lowest possible point.

The Author wishes to express his thanks to Messrs. Aldridge & Ranken, Sir. Wm. Arrol & Company, R. Dempster & Sons, Leech, Goodall & Company, West's Gas Improvement Company, and W. J. Jenkins & Company for the loan of lantern slides and photographs of their special types of machinery, from which he has selected and prepared the various diagrams and illustrations.

Discussion.

The **President** said he was sure that all present had been interested in hearing the description which the author had given of the various machines in use at gasworks. Those who were interested in gas plant would criticise the details, while those who were less concerned with the gas industry would find in the paper good examples of present day methods in the organisation of works with a view to economy. If we were to maintain our position in competition with other countries, and, in the case of individual works, obtain favourable results compared with other works, we must carefully consider the question of economy in working, which was one that would bear much discussion and required a great deal of experience. The Society highly appreciated authors who took as much trouble as Mr. Lister had taken, and who placed such useful material before the members. He therefore had pleasure in asking the meeting to accord a hearty vote of thanks to the author. This was done by acclamation.

Mr. R. C. Macdonald wrote saying :—

The D.B. charging machine which Mr. Lister describes pretty fully, has several very attractive features, but it appears to me to be a machine that would give a gas manufacturer some concern, especially in times like these when the question of obtaining coal of any description is a difficult problem, and to maintain a constant supply of a uniform class of coal must make the problem a much more difficult one.

Mr. Lister says that the groove in the guide pulley is made 3½ in. to 4½ in. deep according to the class of coal used, which suggests that the same class of coal must be used.

Again, the speed of charging varies with the class of coal used and also with the weight of charge. These variations of speed appear from Mr. Lister's description to be left to the attendant. If this is the case it must be a very objectionable feature, and it will be almost impossible to obtain anything like uniform charges. It appears to me, also, that in addition to the coal being of one class, to obtain successful working it will be necessary to have the coal free from moisture, and when working direct from railway wagons or barges it will often be difficult to avoid having a good percentage of moisture in the coal. Unless these difficulties can be overcome, the advantage of having only one machine for a 20 ft. through retort will be very doubtful.

In the case of the Arrol-Foulis charging machines, they can be adjusted to give any desired weight of charge and will go on giving a uniform and level charge until re-adjusted, without having to depend on the attendant.

The D.B. pusher appears to me to have too many working parts which have to enter the heated retort and consequently will require a lot of upkeep. The Hunter, Barnett or Copartner pusher has the advantage of simplicity and when operated by hydraulic power the water inside the rams has a cooling effect on them, and I think that even where the D.B. charges are giving satisfaction, the Hunter, Barnett pusher could be used to advantage in conjunction with them. Objection may, of course, be taken to have the two powers in one works, but sight should not be lost of the fact that although electricity has many advantages, particularly in high speed work, there are many operations in large plants that can be much better handled by hydraulic power. Take for example the wagon tipping arrangement described by Mr. Lister, it cannot compare for simplicity, or ease of working, with the common hydraulic ram type.

In connection with our electrical generating plant we have two of these tippers, one at each end of the elevator hopper, the idea being to save shunting, as many of the wagons have only a door at one end. These tippers have required no attention except an occasional rub of grease on the rams, for several years, and they also have the advantage of being fool proof.

In most large structural works, electric, hydraulic, and pneumatic power are working side by side, and I know of no manager who would care to part with any of the three.

It would be interesting if Mr. Lister could give us some information as to the comparative cost of upkeep between the band, scraper, and bucket conveyors, and also up to what temperature it would be advisable to use a band conveyor in.

One of the most important points to study in designing machinery for coal and coke handling, and particularly the latter, is the reduction of working parts, and especially pins and rollers.

Mr. G. M. Gill said he thought that Mr. Lister had given an excellent idea of the machinery used in gasworks. The author had described the coal breakers as used in gasworks, but there was one point about them which he had not mentioned, and which was rather overlooked in a great many gasworks, and that was the position of the breaker. He (Mr. Gill) had had experience for some years of a works where the breakers were placed on the hoppers and broke the coal as it came in. The coal was brought in by ship, and the cranes unloaded on to the breakers, so that the breaking was done once for all as the coal came into the works.

Then Mr. Lister had not mentioned anything about automatic weighing machines for coal. They were not generally used on gasworks, but he (the speaker) thought that in the future they were almost bound to come into general use. He had some experience of a coal-handling plant where all the coal as it came into the works passed through an automatic weighing machine, which dealt with the coal most satisfactorily.

In the written criticism of Mr. Macdonald the advantages of hydraulic plant over electrical were dealt with, and there was really something in that point. He (Mr. Gill) thought that the hydraulic charging machine undoubtedly put in a better charge than the electrical machine described by Mr. Lister, and most gas engineers had come to the opinion that a full charge or as heavy a charge as could be got into the retort was of advantage in the better results obtained. In his experience the hydraulic machine put in the full charge a good deal better than any electrical machine, but of course there was the disadvantage with hydraulic machines that there had to be two machines to do work that could be done by one electrical machine. With electricity in gasworks it was the regular practice for the gasworks to have their own power generating plant and dynamo worked by a gas engine.

Mr. A. C. McNinn said that the author appeared to have had the experience that tray conveyors were very disadvantageous as to cost. He (Mr. McNinn) had had a good deal of experience with tray conveyors, and with chain conveyors, and he had found with the tray conveyor that although one had to watch it more carefully, and there was more continuous expenditure, still when the total cost was run out there was not very much in favour of the chain conveyor with regard to expenditure on wear and tear.

Mr. G. F. Zimmer said that he congratulated the author. He thought that the moment was a very opportune one for bringing such a subject forward because it was necessary to save as much labour as possible.

He was not sure what was the difference between the push bar and the push plate. Perhaps the author would explain it.

Mr. D. C. Cross (Walthamstow) said that most of his experience was now with the vertical conveyor, and he thoroughly agreed with Mr. Lister that one of the best conveyors for handling coal was the gravity bucket type. He quite agreed with what Mr. Macdonald had said in his written criticism that for truck tipping the hydraulic arrangement appeared to be the simplest, as there was no cost of upkeep. A tipper which had been fixed at his works for twelve years only required as upkeep the rubbing of grease on it once a week.

Mr. A. C. McNinn said, that he wished to ask the author a question with regard to the bar pushers. He would like to know the author's experience with regard to whether the round bar or the flat bar gave the greatest breakage of the coke. It was an interesting point.

The Author in replying, said he thought most of the points that had been raised by the various speakers had regard to the advantage of hydraulic power over electric power for certain purposes at gas works. He should be the last to recommend electric power or any other mechanical power for tippers and work of that sort if there was hydraulic power already installed, but in many cases with which he had been concerned there had not been any hydraulic power at all available, and he thought that under those circumstances it was preferable to put in a mechanical arrangement which could be driven off the engine or motor (which had, in any case, to be put in to drive the coal plant), rather than to go to the expense of a pump and generally an accumulator. He did not say that an accumulator was always necessary, but in his experience it was advisable to have one, and he thought that by the time the pump, accumulator, piping and other arrangements had been put in, the cost would be considerably more than the mechanical arrangement.

The discussion seemed to show that for several purposes hydraulic power was better than electric.

Mr. Macdonald in his written communication had mentioned the question of a ram at each end or side of the receiving hopper to allow for waggons coming in either end first. That plan was often adopted with the mechanical arrangement which had been shown on the screen. He quite agreed that the upkeep of an hydraulic ram was comparatively inexpensive, but he did not think that the upkeep of the mechanical tipper, for instance, which he had shown, would be any more expensive. An hydraulic ram for discharging a retort was very simple and worked extremely well, and if hydraulic power was available, apart from the mess that water generally made in the retort house, which was not a drawing-room at the best of times, there was not very much objection to it.

Mr. Macdonald had questioned the necessity of the coal being uniform. There was really no necessity for that at all. The type of " projector " charging machine which had been described was not the only machine of the projector type which had been installed in fair numbers, but he had not an illustration of the other types, so he had avoided referring to them particularly. Provided that the coal was broken down to a convenient size, anything under two inches cube, the De Brouwer projector type of machine would deal with it quite comfortably, whether it was dust or lumps. The ideal class of coal for these machines was washed coal of bean size, which charged in extremely well. Dust required a higher velocity in order to get it to the far end of the retort. Lumps required a less velocity, but after the first charge or two had been put in the operator could tell what, if any, alteration at all was required to the speed of the machine. Generally it was not from hour to hour that the class of coal varied in a gas works, but from consignment to consignment, so that the quality generally remained fairly uniform for some days at any rate. As a practical point he thought that, generally, the operator had a mark on his machine to show what notch to put the speed regulator on to and he ran the machine at that speed for any one class of coal. Under ordinary circumstances there was very little difference in the result unless there was a very wide variation in the quality of the coal.

It was not at all necessary for the coal to be free from moisture; in fact he knew some places where the coal was purposely wetted before it was put into the retort.

The automatic weighing machines which Mr. Gill had mentioned were certainly extremely useful and were being installed in a number of cases now. The majority of them were, he thought, of the Avery hopper type which automatically recorded the weight passing through ; but in the case of Telpher plants, as he (the author) had mentioned in showing the photograph of the Hackney plant, the weighing machine was embodied in the track, and every time the loaded Telpher ran over the floating portion of the track the weight was recorded and integrated.

With regard to Mr. McNinn's remarks as to the upkeep of the tray conveyor, he must say that his own experience of tray conveyors had been mainly with coke-oven plants, and there they certainly had a very bad reputation.

As regards the breakage of coke with the conveyors, he thought that it was general experience that the round bar caused more breakage, and, in fact, it had practically been discarded. It was never put in in any new installations that he had knowledge of. It was the original pattern of chain, and it was the easiest to make and the cheapest, but the flat bar was better because there was no tendency for the bar to ride over and crush the coke in the trough. It dragged it along more easily, and particularly where the conveyor, after leaving the retort house, rose at an incline the flat bar was much more efficient. With the round bar there was a tendency for the coke to be continually rolling over the bar. The flat bar helped to prevent that.

Mr. Zimmer had asked about the difference between the push bar and the push plate conveyor. The push bar conveyor that he (the author) had mentioned was practically of the same type as the hot coke conveyor, only the bar was about six inches deep and fitted into the trough in the same way as the scraper of the push plate conveyor. The strands of chain were formed in the same way as the coke conveyor chain, namely, of stampings, and they were not carried by rollers. The push plate conveyor generally consisted of a wrought iron or steel plate bolted to a cross spindle or cross piece, but in the push bar conveyor the cross bar was generally a steel casting, cast in one with the blocks at the end.

He quite agreed with Mr. Cross that the gravity bucket conveyor was for vertical installations really the best arrangement to adopt. He did not know whether it was owing to liability to break down or not, but he knew a number of vertical retort installations where a hoist was put in in addition to the G.B. conveyor to act as a standby and also for elevating the coke. Although coke as well as coal could be elevated by the gravity bucket conveyor, engineers, ordinarily, seemed to prefer to run the hot coke into bogies and elevate it in a hoist.

Mr. H. C. Widlake wrote :—

(1) No mention is made of the excellent performance of separate projector and ram " D.B." machines in regard to the time taken to stoke a retort. This figure should be well under a minute, and should create a most favourable impression on

prospective users of stoking machinery, as would also data concerning the number of retorts completely stoked by the expenditure of, say, one B.T.U. of electricity. I have only " F.A." figures by me, but in the case of the " D.B." separate machines I should imagine one unit would suffice for the handling of seven or eight 20ft. through retorts.

(2) In regard to coal and coke handling machinery, the use of electricity for operating the same enables an invaluable check to be kept upon the general condition of the conveyor or elevator as the case may be by the use of integrating watt meters on the respective motor circuits. No form of power application lends itself so aptly to this practice as does electrical driving, and the records obtained enable one to keep their finger on the pulse of the plant, so to speak, and to detect little incipient defects and fallings off in efficiency, which, with any other form of driving, would have to develop to a serious extent before becoming apparent.

Take the case of one of our drives, for instance. We have a large conveyor of the push plate type on which we handle approximately 200 tons of coal per day, while our watt meter shows a daily consumption of 70 units of electrical energy. Since the altering of the driving arrangements in this conveyor four years ago the relation between the current used and the material handled has been most consistent, and any mechanical defect in the conveyor chain or driving head invariably shows itself in the figure representing coal handled per unit of electricity, usually 3·5 tons.

We do not regard the check as most valuable in regard to the motor, but rather in regard to the mechanical arrangement of the conveyor, and it has enabled us on many occasions to detect incipient faults and apply the stitch in time.

The same argument may apply to all the machinery on a gas undertaking, and the initial expense of such meters is trifling as compared with the benefits which accrue from their use.

English gas undertakings, as a whole, are rather slow to take advantage of this characteristic of the electric drive, and regard such meters as being more ornamental than useful. On the Continent, on the other hand, I believe their value is fully appreciated, and in some works they form a standard portion in every power drive.

In reply to Mr. Widlake's remarks the author agrees that electrical records of the kind mentioned are often extremely useful as a check on the correct working of the plant. The author finds from his records that the average current taken by a combined charging and discharging machine is about 12 to 15 ampères at 220 volts, which gives approximately 9 retorts charged and discharged per unit. If the power is generated on the works by means of a gas engine, the cost of generating current, taking gas at cost in gasholder, will be about ·75d. per ton of coal carbonised, including also the breaking and elevating of the coal.

It is extremely useful to have some record of the power required, as this certainly affords a very good check on the working of the plant, and, as mentioned by Mr. Widlake, electrical drives offer considerable advantage in this respect. It is certainly good practice to fit an integrating watt meter, or some similar instrument, on the main switchboard.

THE SOCIETY OF ENGINEERS (INCORPORATED).

BALANCE SHEET. 31st December, 1915.

Year ended 31st Dec., 1914. £ s. d.	LIABILITIES.	£ s. d.	£ s. d.
152 16 2	Sundry Creditors		131 5 3
26 4 10	Subscriptions in advance ...		18 4 0
	Life Membership Account—		
	As per last Balance Sheet ...	70 10 6	
	Less 5% transferred to Income on account of Life Subscriptions expired	3 10 6	
70 10 6			67 0 0
	Society's Premium Account—		
	As per last Balance Sheet ...	22 3 5	
	Add President's Donation ...	5 5 0	
		27 8 5	
22 3 5	*Deduct* Cost of Premiums ...	18 8 8	
			8 19 9
	Status Prize Account—		
8 8 0	As per last Balance Sheet ...		8 8 0
5 0 8	*Clarke Premium Account*—		
	Benevolent Fund Account—		
	As per last Balance Sheet ...	61 12 11	
	Add Interest at 4%	2 9 4	
61 12 11			64 2 3
	Accumulated Fund Account, being excess of Assets over Liabilities		
	As per last Balance Sheet ...	760 12 2	
	Add Balance from Income and Expenditure Account	19 10 3	
760 12 2			780 2 5
12 3 5	Prize Accounts (see separate statements)		—
£1,119 12 1			£1,078 1 8

Year ended 31st Dec., 1914. £ s. d.	ASSETS.	£ s. d.	£ s. d.
	Cash—		
121 15 4	At Bank, Current Account ...	94 5 3	
150 0 0	Do. Deposit Account ...	200 0 0	
15 15 7	In hands of Secretary ...	8 5 10	
			302 11 1
	Sundry Debtors—		
	Subscriptions in arrear and received at date of Auditors' Certificate	6 6 0	
	Advertisements in Journal, etc.	6 2 7	
	Payment in advance	4 4 0	
30 17 0			16 12 7
	Investments—		
	£606 L. & N.W. Rly. 3% Debenture Stock at 86½, as per last Balance Sheet	524 19 0	
	£300 India 3½% Stock at cost, as per last Balance Sheet ...	278 13 6	
		803 12 6	
	Less Reserve for depreciation	115 0 0	
			688 12 6
723 12 6	(The market value of these securities at 31st Dec., 1915, was £687 13s. 2d.)		
	Office Furniture—		
	As per last Balance Sheet ...	28 5 8	
	Less depreciation at 10% ...	2 16 7	
28 5 8			25 9 1
	Library—		
	As per last Balance Sheet ...	32 11 7	
	Less depreciation at 10% ...	3 5 2	
32 11 7			29 6 5
	Stocks in hand—		
	Transactions and Journals ...	15 0 0	
	Law Lectures	10 0	
16 14 5			15 10 0
£1,119 12 1			£1,078 1 8

THE BESSEMER PRIZE FUND.

Year ended 31st Dec., 1914. £ s. d.		£ s. d.	£ s. d.	Year ended 31st Dec., 1914. £ s. d.		£ s. d.
160 7 6	As per last Balance Sheet	160 6 9			£185 N.E. Railway 3% Debenture Stock	
	Less Investment Depreciation Account	22 4 0		154 9 6	At market value 31st December, 1915	132 5 6
			138 2 9	5 17 3	Cash in hand	5 8 2
5 4 3	*Add* Income from N.E.Rly. Deb. Stock		5 0 2			
165 11 9			143 2 11			
5 5 0	*Deduct Cost* of Premium		5 9 3			
£160 6 9			£137 13 8	£160 6 9		£137 13 8

THE NURSEY PRIZE FUND.

£ s. d.		£ s. d.	£ s. d.	£ s. d.		£ s. d.
46 10 5	As per last Balance Sheet	48 4 7			£33 Hammersmith & City Rly. Consolidated Ordinary Stock.	
	Less Investment Depreciation Account	11 2 8		46 7 3	At market value 31st December, 1915	35 4 7
			37 1 11	1 17 4	Cash in hand	3 10 0
1 14 2	*Add* Income from Hammersmith and City Rly. Ordinary Stock		1 12 8			
£48 4 7			£38 14 7	£48 4 7		£38 14 7

THE BERNAYS PRIZE FUND.

£ s. d.		£ s. d.	£ s. d.	£ s. d.		£ s. d.
26 7 8	As per last Balance Sheet	27 5 1			£13 N. & S.W. Junction Rly. Stock—	
	Less Investment Depreciation Account	14 3		22 16 3	At market value 31st December, 1913 (No later quotation available)	22 2 0
			26 10 10	4 8 10	Cash in hand	5 5 3
17 5	*Add* Income from N. & S.W. Junction Rly. Stock		16 5			
£27 5 1			£27 7 3	£27 5 1		£27 7 3

THE SOCIETY OF ENGINEERS, (INCORPORATED).

INCOME AND EXPENDITURE ACCOUNT, FOR THE YEAR ENDED 31ST DECEMBER, 1915.

Year ended 31*st Dec.*, 1914. £ *s.* *d.*	EXPENDITURE.	£ *s.* *d.*	£ *s.* *d.*
	To Printing "Transactions" ...	139 2 6	
	Less Sales and Advertisements	31 5 7	
150 6 0			107 16 11
	, *Administration Expenses*—		
300 0 0	Salary of Secretary	300 0 0	
83 11 6	Rent of Offices	85 0 0	
15 16 0	Fuel, Lighting & Office Cleaning	21 0 5	
22 12 9	Redecorating Offices ...	—	
90 0 1	Postage, Telegrams, Carriage and General Expenses ...	67 2 1	
62 2 11	Stationery & General Printing	39 12 11	
10 10 0	Audit Fee	10 10 0	
			523 5 5
	,, *Meeting Expenses*—		
19 19 0	Hire of Rooms	13 13 6	
—	,, Lantern	1 6 0	
15 15 0	Reporting Meetings	15 15 0	
6 6 7	Refreshments for Members at Ordinary Meetings ...	5 5 11	
			36 0 5

Year ended 31*st Dec.*, 1914.	INCOME.	£ *s.* *d.*	£ *s.* *d.*
740 5 4	By Subscriptions (excluding all arrears not realised at the date of the Auditors' Certificate)		672 4 10
34 13 0	,, Admission Fees		41 8 6
3 11 1	,, Interest on Deposit		5 17 2
	,, *Interest on Investments*—		
17 1 11	London & North-Western Rly. 3% Debenture Stock ...	16 7 6	
9 17 0	India 3½% Stock	9 5 11	
			25 13 5
1 0 0	,, Law Lectures Balance ...		19 4
1 1 6	,, Examinations Account ...		—
—	,, Sundry Receipts		8 0 0
16 7 6	,, Balance being Excess of Expenditure over Income ...		—

—	,, Lecture Expenses	4 14 6			
6 0	,, Employment Bureau ...	—			
29 17 4	,, Smoking Concert Balance ...	—			
—	,, Donation (P.C.W.R.C.) ...	2 10 0			
7 11 6	,, Law Charges	16 14 8			
3 2 10	,, Depreciation of Office Furniture	2 16 7			
3 12 5	,, ,, Library ...	3 5 2			
2 7 5	,, Interest on Benevolent Fund	2 9 4			
—	,, Balance being Excess of Income over Expenditure ...	54 10 3			
£823 17 4		£754 3 3	£823 17 4		£754 3 3
					£ s. d.
	To Reserve for Depreciation of Investments	35 0 0		By Balance brought down ...	54 10 3
	,, Balance carried to Accumulated Fund	19 10 3			
		£54 10 3			£54 10 3

We have examined the above Balance Sheet and Income and Expenditure Account and have obtained all the information and explanations we have required. In our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Society's affairs according to the best of our information and the explanations given to us and as shown by the books of the Society.

3, Raymond Buildings,
Gray's Inn, London, W.C.
18*th February*, 1916.

(Signed) BEGBIE, ROBINSON, & COX,
Chartered Accountants.

1st May, 1916.

MR. PERCY GRIFFITH, M.INST.C.E., PRESIDENT,
IN THE CHAIR.

ENGINEERING AND SCIENTIFIC RESEARCH.

By J. A. FLEMING, M.A., D.Sc., F.R.S., M.Inst.E.E., University Professor of Electrical Engineering in the University College, University of London.

THERE seems to be a very complete agreement that one result of the great war in which we are engaged will be to render absolutely necessary certain reforms in our national systems of education and especially in the attention given to pure and technical scientific knowledge. Hardly anyone disputes the propositions that scientific discovery and research must be brought to bear more fully on our national industries, and must be encouraged to a far greater extent than heretofore in this country; but the moment we go beyond these generalities we find great differences of opinion as to the best mode of giving effect to these desires.

Many scientific men have long and vehemently urged national attention to this matter, but the want of co-ordination between our various learned and technical societies and the strongly conservative element in our older Universities and public schools which resists a break with the past have prevented many useful changes being made.

The Board of Education Scheme.—An important step was, however, taken by the Government through the Board of Education last July in the establishment of a Committee of the Privy Council and the appointment of an Advisory Council to deal with the question of scientific and industrial research as described in a scheme outlined in a White Paper. As this Committee and Council have already come into existence we cannot regard the Scheme as merely a proposal to be discussed. We must accept it in a sense as an accomplished fact, but one in which the details may, we hope, be considered as open to modifications.

Since any such Government control over scientific research is bound to have a great influence in time on the direction of scientific work and its applications, it appears most desirable to gather views upon this scheme even after its inception, from those who are concerned with one of the most scientific of these industries, viz., engineering in all its branches.

It is estimated that the capital invested in Great Britain at present in plant and materials in the two branches of mechanical and electrical engineering is probably not less than £1,000,000,000. When we bear in mind the manner in which a single perfected improvement or invention can revolutionise a whole industry it needs no further argument to prove the necessity for careful attention to the progress of scientific research in connection with it. Hence it seems extremely important that engineers should have the opportunity of discussing schemes proposed, or already launched for dealing with industrial and scientific research lest steps should be taken to give permanent form to proposals without sufficient consultation with those who will most be affected thereby.

It is a very widely held opinion that all that is required to effect reforms are Acts of Parliament, the formation of Committees, or the issue of regulations. Many instances could, however, be called to mind of legislation undertaken with all apparent care, the effect of which has been exactly the opposite of that intended. Electrical engineers will no doubt remember an Act of 1882, somewhat ironically termed "An Act to facilitate Electric Lighting," which was passed almost coincidently with the completed invention of the incandescent electric lamp, the immediate consequence of which was to throttle effectively this nascent industry in Great Britain for six years.

Necessary Improvements and Reforms.—In the particular matter under discussion we have been compelled to recognise the manner in which important industries have died out or never thriven in this country in consequence of our neglect of scientific education and research. It is equally important to realise that we cannot undo the effect of this neglect by a wave of the wand, but that reforms to be useful must be very deep and very thorough and begin at the top and at the bottom in our systems of national education. Whilst we cannot hope to reach anything like unanimity on a subject so complex as the means of imparting or creating knowledge, it is of the utmost moment that engineers should carefully consider the various proposals made for reforms, so as to bring to bear their practical experience on it and not permit schemes to advance too far which are the product merely of academic or political thought.

We have to consider then—

(i.) The improvements in the training of men who will become engineers.

(ii.) The best means by which scientific knowledge can be brought to bear on the problems of engineering.

(iii.) The scientific method in relation to the business side of engineering.

The enormous destruction during the war of the products of the engineer's shop and office will call for reconstruction, and offer a vast field for engineering work on its conclusion. We have to see to it that as much as possible of this work falls into the hands of the United Nations which form the British Empire.

This work will make a call for men trained both in the scientific and practical side of engineering and also for others proficient in the business aspects of it.

It is unquestionable that the success of the Germans in the commercial field is in part due to their system of national education, which prepares every man for some vocation and does it thoroughly. We are by no means desirous of copying it in its entirety as it possesses grave defects on its ethical side and in its extreme cultivation of materialism in its worst aspects. Nevertheless, we can usefully draw some lessons from it.

Our own educational systems from bottom to top are too bookish, too much devoted to the cultivation of memory and words, and not sufficiently leavened by a real knowledge of the facts of nature and power to draw true inferences from observations. The success of the Montessori system of training young children and of the Baden Powell Boy Scout movement in imparting self-directing power and vivid interest in learning about things, shows what can be done on right lines.

We have to bring the same principles to bear on all other departments of education. One barrier in the way of our industrial progress has been the imperfect scientific training of foremen, managers and young heads of departments in many engineering works. The young men who are brought in to fill directing positions have generally received the usual public or middle class school education with its entirely insufficient attention to scientific subjects. Even when this has been supplemented by a course at a technical college the time at the latter has been so much taken up with learning things which ought to have been learnt at school that the opportunity of acquiring advanced scientific knowledge or real power of independent investigation has been very much curtailed. Hence when once immersed in business it has been impossible for them to keep up with scientific advances, and they can at most copy what they see others do. We have to produce more men who can do new things, and not merely know about old ones.

Until this state of affairs is remedied it is perfectly futile for Great Britain to hope to gain pre-eminence over Germany in scientific industries. The advantages which we have in greater originality of mind and better workmanship are neutralized to a large extent by the want of a sufficiently thorough and broad scientific education to enable us to see the practical value of, and work out exhaustively, and especially with reference to trade purposes, the openings given by scientific discoveries. It is the want of this sufficiently thorough scientific education which accounts for the limited faith of many employers and capitalists in scientific research and also for the inability of the practical worker to take advantage of, or see the meaning of facts which present themselves to him in his every-day work.

One of the educational reforms which seems most necessary is the compulsory attendance of lads after leaving the Board School at a technical continuation school. Assuming he leaves at 14 or 15 and is taken on at an Engineering Works it should not be optional whether he attends a continuation technical school. He should be compelled to do it until he is 17 or 18 years old, as in Germany. This continued education should not be merely a handicraft training but should be a careful instruction by practical men who are or have been engineers; in mechanical drawing, graphics, mechanics, physics, chemistry, metallurgy, electrotechnics and machine construction. The attendance should not be allowed to become irregular and the certificates of proficiency should have an immediate effect on the lad's prospects of advancement.

In the case of young men of higher social rank who have been to public schools I am very strongly of opinion that the practical experience in the shops and drawing office should not be deferred entirely until after the College Course. The school education should have provided him with a thorough grounding in the elements of Chemistry, Physics and Mathematics, pure and applied, and with a speaking acquaintance with at least one modern language. One year at a University or Technical College should then prepare him to take advantage of some shop experience and after that he should return to the College for a year or perhaps two for the Advanced Laboratory and Designs Work.

The Degree or Diploma Examinations should be made to depend more than they are at present on the results of practical laboratory and drawing office work. My experience is that students who come straight from school to college for three years without break are apt to spend much time in mere amusement and are less serious workers than those who have had some experience in an engineer's shop and then returned to the College.

In order to compress into this time the necessary training our methods and means of instruction must be much improved. It is essential now for every engineer to have a good working acquaintance with certain branches of mathematics. If he has no knowledge whatever of the Calculus or Trigonometry he finds it impossible to read many original papers in the Technical journals. In teaching electrotechnics to young engineers I find I have to give much time to imparting elementary mathematical knowledge which ought to have been gained elsewhere. It should, however, be taught by Engineers to Engineers.

The great thing to guard against on the part of the student is premature specialization. He should broaden as much as possible his knowledge of the principles of Chemistry, Mechanics, Physics, Mathematics, and Metallurgy, and he will then be able, later on, to build up on this foundation. Unless he does lay this foundation he will not be able to follow or assist in improvements. As an illustration of this we may take subjects such as Telephony or Wireless Telegraphy. It is impossible now for anyone to make any really important addition to these subjects who has not a very competent knowledge of physics and some parts of mathematics. The easier problems are worked out and the design of telephonic systems or radiotelegraphic stations has become a matter in which advanced scientific knowledge is an important factor. Then again to make any advance in metallurgy requires a very intimate acquaintance with the chemistry of metals. A lucky accident might give a clue to an improvement, but an observer not sufficiently acquainted with modern chemical principles could not take advantage of it or follow it up.

In the third and fourth year the student will, of course, have given time to learning as much as possible of the methods of testing both mechanical and electrical—as are required in Engineering work, the especial object of which is to enable him to deal with the kind of problems which will present themselves in practice.

It is of extreme importance that he should acquire sympathy with and confidence in scientific research to give the data for engineering work.

The Relation of Scientific Research to Engineering.—We turn then to the subject which it is our purpose more particularly to discuss, viz., the relation of scientific research to engineering practice. We may roughly divide this research work into three departments.

There are first the laboratory researches which aim at determining various physical constants of the materials used in engineering which are requisite to give data for design. This knowledge can never be made too accurate or too complete; but the moment one goes to any of the well-known pocket books or Tables of Engineering data it is astonishing to find the wide gaps in our knowledge. Hence we require abundant provision for re-determining these values for particular samples of new materials to be used in bulk for various purposes.

Then in the second place there are those researches which aid engineering by providing new methods of examination and test of materials or structures. As an instance of this, consider the invaluable aid rendered by what is now called Metallography or the study of the internal structure of metals and alloys by the aid of the microscope. The founder of this branch of investigation was Dr. Sorby of Sheffield, in 1864, who first began the microscopic examination of iron and steel. Every engineering student is now familiar with the processes applied and with the immensely important knowledge that has been gathered as to the composition of steels and other alloys by this method.

The great development of pyrometry and high temperature thermometry by the invention and improvement of the thermojunction and radiation pyrometer and the electrical resistance thermometer, due to the scientific labours of Callendar, Le Chatelier, Holborn, Féry, and many others have provided the engineer with implements of great accuracy for the measurement of high temperatures and made it, in fact, an exact science.

The improvement in the means of testing the mechanical or elastic properties of engineering materials by testing machines is another instance of the same class of research. Of late years the appliances for testing the mechanical properties of materials under repeated stresses, vibrations or blows have become important in giving the dynamic as contrasted with the static stress properties. One of the latest additions to the resources of engineering testing is the very ingenious application of polarised light by Professor E. G. Coker to study the distribution and magnitude of stresses in celluloid models of beams, struts or rivetted plates used in engineering structures. To this class of research we may add such methods as those introduced by Froude for ship designing. Froude invented the method of predetermining the resistance to propulsion of a ship by dragging small scale models of ships' hulls made of paraffin wax through water in an experimental tank. The tractive force required is recorded graphically by a dynamometer. He discovered two very important laws, viz., the law of the "corresponding speeds" and that of the variation of resistance with the length of the ships when moving at corresponding speeds. These laws and methods are of the greatest use in ship design. Is it not possible that the same methods might be applied to determine the resistance of air to moving trains and motor cars, so that experiments with model vehicles would give data for design? It is being applied to the study of aeroplanes and of the problem of flight generally.

Then in the third place we have a type of research which calls for special aptitude and insight, viz., those which lead to the discovery of some new process, material or machine.

An excellent example of this is the discovery made simultaneously by C. M. Hall in America and P. Héroult in France when hardly more than students, which finally rendered the production of metallic aluminium in bulk a commercial success.

The process is founded on the fact that fused cryolite dissolves alumina and that if an electric current is passed through the fluid mass at a low voltage it not only keeps it fluid but electrolyses the alumina without affecting the solvent ; and since metallic aluminium has a slightly greater density than the electrolyte it falls to the bottom of the cell and is not re-oxidized but can be drawn off in the metallic state.

Further examples of the same important class of researches are given in the production of the various alloy steels, for example, tungsten, vanadium steels, and so on, with their extremely valuable properties. A certain nickel-chromium alloy called nichrome has been found to be of great service in electric heating by providing an inexpensive alloy which does not rapidly oxidize at a bright red heat.

Then we have additional illustrations in the galaxy of inventions which have made the internal combustion engine, aeroplane, steam turbine, wireless telegraphy, the polyphase alternator and asynchronous motor such epoch-making appliances. Whilst the initial ideas in these things were all the outcome of genius their development has required the steady application of the scientific method and the commercial ability to find the means of doing it.

The really important question is, what are the conditions under which we can stimulate this originative power ? It is partly due to natural gifts ; partly to effective training and partly to the possession of sufficient appliances and means.

Laboratories may, however, be built without number and Chairs and Scholarships endowed, but unless the right men occupy them very little results.

The true answer to the above question is, I believe, that originality stimulates originality. A really great investigator not only discovers himself but imparts something of his powers to his associates. No-one can have worked under Lord Kelvin or studied under Clerk Maxwell without having caught from them some inspiration and some small fragment of their passion for the discovery of new truths and methods of doing it.

Hence we require to establish and strengthen those research institutions such as the Cavendish Laboratory, Cambridge, or the Royal Institution, London, where notable scientific investigators have established schools of research and imparted some of their great powers to students and colleagues. But the subject we are especially discussing is not scientific research in itself but research in relation to engineering.

The Engineer requires scientific assistance first in the accurate determination of certain constants and data concerning materials and structures. Also certain very accurate gauges and measuring tools.

The work of furnishing these must be beyond suspicion in accuracy and authoritative in effect. Hence it can only be done in a national institution like the National Physical Laboratory.* The Engineering Standards Committee of the various Engineering Institutions has, however, rendered invaluable service by settling specifications for materials and sizes to be used in engineering and in securing for them general acceptance.

In providing a large mass of accurate scientific data for use in Engineering ; Electrical, Mechanical, Hydraulic, and Illuminating, the National Physical Laboratory has given most valuable service to Engineering for the last twenty years. Nevertheless there are matters requiring assistance for which even its present resources are insufficient.

There are problems in connection with Electrometallurgy and Engineering which await solution for which our present appliances in private or University Laboratories are insufficient.

We need in addition to the present resources of the Engineering Department of the National Physical Laboratory an increase in the facilities for metallurgical research work on a large scale, such as that conducted with valuable results in University College, Sheffield. Such a laboratory should be provided with full size smelting and refining furnaces by coke, gas, and electric heating and with testing machines capable of dealing with test objects of commercial size even full sized bridge members.

The Engineering Laboratories of some London Colleges, such as University College, should have their accommodation and appliances largely increased. It would be of great advantage if these Laboratories were so equipped as to specialize in certain lines of research and brought into closer contact with the problems requiring solution in connection with actual engineering work.

---

* The writer may, perhaps, be permitted to recall to mind that in November, 1885, he read a Paper to the *Society of Telegraph Engineers and Electricians* afterwards called *The Institution of Electrical Engineers* on " The Necessity for a National Standardizing Laboratory for Electrical Instruments." In the discussion on that paper about eighteen speakers were unanimous in approving the proposals in it. The Society appointed a Committee to further the suggestion, but want of funds prevented anything being done at the time. The writer spent much time in the next two years in working out the details of such a laboratory with the late Major P. Cardew, R.E. On June 19th, 1889, a deputation was received by the then President of the Board of Trade representing the Institute of Electrical Engineers and the London Chamber of Commerce urging the Establishment of a Board of Trade Standardizing Laboratory. This was done in the following year. In 1891 and 1892 Sir Oliver Lodge brought to the notice of the British Association the necessity for a National Physical Laboratory, and a year or two later the late Sir Douglas Galton described in a Presidential address the recently established *Reichsanstalt* in Berlin or State Physical Laboratory. Shortly afterwards our own National Physical Laboratory was established very much on the lines indicated in the writer's paper of 1885.

Much of the work carried out would then be of a highly confidential character, and might have to remain unpublished but be communicated privately to Firms and Corporations concerned with the subjects of the investigation.

Industrial Co-operative Research —In Germany much of the technical research work is carried out privately by private associations of the trades concerned. In Great Britain manufacturers in the same trade are far too prone to regard one another as rivals, whereas in the future they will have to stand much more shoulder to shoulder against their common and German antagonists who will be united against them.

Hence in many matters it would pay British firms in the same business to promote scientific research in common on certain problems of manufacture, subscribing together the funds to undertake it either at a National Technical Laboratory or at some Technical College or University which may be provided with the proper equipment. Such information when obtained would then only be communicated to the members of the Association or Union.

Then, again, the same principle of common action might be brought to bear upon the collection of information as to what is being done in certain branches of manufacture ; the establishment in fact of an Information Bureau common to certain Firms or Manufacturers. There are, as every one knows, already in operation many powerful and important Trade Associations, such as the British Electrical and Allied Manufacturers Association (B.E.A.M.A.), and many other kindred organizations which are doing and could extend this work with great effect.

It is certain that, as a rule, British technical firms do not expend anything like the same labour or money over their intelligence departments as German firms. The latter gather in from all countries every scrap of information which can assist them, both fromscientific and technical papers and patent specifications. This is carefully digested and classified so that they are able to keep careful watch on progress in their own subject. The smallest valuable novelty is then carefully tested in practice.

The first direction in which our advances should be made is in improving the means for obtaining this early information on possible improvements and advances. In gathering in and bringing to early notice technical improvements greater assistance might, perhaps, be rendered by our technical papers and the Proceedings of our Technical Institutions.

The field of knowledge is now so vast and technical literature so voluminous that it is becoming increasingly difficult for the busy engineer, whose day is occupied with settling contracts, specifications or routine work in an office or factory, to keep himself apprised of new departures in his own special work, even with the aid of all our ably conducted technical journals.

We need to improve in every way our means of classifying and notifying technical and scientific novelties and patent applications so that it may become more easy to keep abreast of progress. But when all this is done we may be as far as ever from making those discoveries and inventions which have value in commercial world.

If we look carefully at the history of successful invention we see that it always involves three things: first, a new idea or fortunate observation; secondly, the persistent following out of this idea to its logical issue by persevering work. The first step is always a stroke of genius, the second stage involves generally skilled assistance by persons of competent technical training. But there is a third stage, viz., the translation of the process or discovery into a commercial manufacture. This stage requires capital outlay and often large preliminary expenditure before any return can be obtained, but also it involves and necessitates high ability in applying the scientific method to the commercial problem. The public do not understand this. They mostly think that an invention leaps full grown from the head of an inventor like " Minerva from the head of Jove."

Everyone has known cases of scientific manufactures or industries which have been nearly brought to ruin under one management and rescued and reconstructed by another. Hence no amount of official organisation of scientific research will necessarily produce successful results unless the men with right judgment and initiative are brought to the front.

The position of the Engineering Institutions in relation to schemes for assisting Industrial Research.—The point which requires consideration is whether the scheme promoted by the Board of Education will meet these requirements of technology and manufacture and especially of Engineering. For one thing it is much to be desired that the Advisory Council should have on it members who represent the constructive and manufacturing side of Engineering in various branches. As at present constituted it is chiefly representative of eminence in pure scientific knowledge. It is satisfactory to find, from the latest report of its decisions and work that as regards assistance given to industrial research, its aid will be given through the intermediation of the established Professional and Technical Institutions or Societies because they embody in their membership the knowledge of the most necessary requirements in the way of such research.

A further reason for it is because many important problems which need attention are very large ones and will require the assistance of many experienced men. Such problems are the conservation and more economical use of our national coal supply; the universal adoption of gas or of electric heating in place of the wasteful combustion of raw coal in domestic fire places, the electrical transmission of power from coal fields to great cities, are examples. The coal question in its various aspects is especially important. Of all European coalfields, Germany has the largest known reserves, though of inferior quality. There are three great coal bearing districts in Germany, viz., the lower Rhine and Westphalian basin, Silesia, and the Rhenish district near Saarbrücken and Aix-la-Chapelle. The life of these fields has been estimated at 2,000, 1,200, and 4,000 years respectively, whereas the figures given by the Royal Commission on Coal Supplies in Great Britain fixed the life of ours at about 200 years. We have, however, the advantage of superior quality of material. Nevertheless we must bring, at once, the highest scientific knowledge to bear upon the subject of our more scientific coal consumption and use. These are matters quite beyond any individual or small committees to deal with, they demand the conjoint consideration of many minds. Hence it is to be hoped that the principal Engineering Institutions will unite in a strong request to the Government, if they have not already done so, to place representative engineers upon the Advisory Council and also that in the disbursement of funds allocated to the assistance of industrial research, these institutions, as bodies, shall be to a considerable extent the avenues through which it is dispensed.

The present policy of the Government and of the Board of Education seems to be the creation of fresh committees and Boards whilst setting on one side the existing learned and technical institutions. The latter are corporate bodies which include in their membership all those who have special knowledge and eminence in their various subjects.

Thus we are promised a plethora of new Committees on various subjects which already fall within the scope of the operations of old established and strong professional societies like the various Engineering Institutions of Civil, Mechanical and Electrical Engineers, and the Iron and Steel Institute, The Institute of Naval Architects and the Society of Engineers.

Mr. Runciman has, recently, appointed certain Committees to report on measures to safeguard the commercial interests of Iron, Steel and Engineering trades and on Shipping and Shipbuilding. The Advisory Council for Scientific and Industrial Research is also appointing Standing Committees to deal with Mining and Metallurgy, both non-metallic and metallic mining and non-ferrous and ferrous metallurgy. Also an Engineering Committee is promised as well. Furthermore, the Royal Society recently called a Conference of about twenty-five of the chief scientific and technical Societies and it was decided to form a Board to advise the Government on any branch of scientific inquiry which may be brought before it.

The result of all this must be to diminish rather than increase the very organization and co-ordination required.

We are told that "in the multitude of counsellors there is safety," but it may seriously be doubted whether the same can be said of a multitude of Committees unless very carefully organized and correlated. The existing scientific and professional societies if properly organised would supply all that is required. These engineering institutions and societies should take a leading part in guiding the fortunes of the industries they represent and not be reduced to the level of mere Paper reading or discussion societies.

The head of the group concerned with pure scientific research should be the Royal Society acting not through a few, but all of its Fellows. At the head of the technical research an organized body selected from the professional and technical societies. At present, the Government prefer to ignore the existing societies and create fresh bodies of their own selection. The result will be to weaken these existing Institutions and Societies.

It is essential to guard against the bureaucratisation of science, and the safest and most simple method of avoiding this would be to make the great technical and professional institutions the means of advising upon the most important steps to be taken in aiding technology. Suggestions have been put forward for the creation of a Ministry of Science. It is difficult to see how any such step will assist matters at present, whilst on the other hand it might be the beginning of a system of bureaucratic control which would involve a cumbersome and expensive machinery with much inertia and delay in giving assistance to genuine research.

We have first to create a great change in the attitude of the public mind towards scientific knowledge and research and develop the conviction that until it is regarded as a most serious pursuit we shall fail to make any firm advances towards victory in industrial war.

The Scientific Organization of the Business Side of Engineering. —Then we must glance in the last place at the applications of the scientific method to the commercial side of engineering.

No one who has studied, even casually, the German methods can fail to admit they have realised fully in commercial matters the truth that union is strength. Whilst British firms are regarding one another as competitors and greatly afraid to exchange information, their German rivals have adopted every possible means to weld together all portions of their commercial enterprise into one great machine. Our ideal has been largely individualism and competition, theirs has been organization and co-operation. The German commercial system is essentially militant in nature and organization. It is all part and parcel of the plan to achieve world conquest at any cost and by every means.

Our post-war policy cannot, therefore, be simply defensive. No tariff wall can be built so high, no boycott of German goods so thorough, as to defend our position in the absence of a positive and vigorous policy of attack.

Hence the first condition of success must be association and combination, and the second the scientific method in all things.

The first principle of scientific investigation is to collect the facts and to draw deductions only by the light of full knowledge.

The inference is that our information about foreign markets must be greatly increased. This means that our Consular Reports must be improved, that foreign agencies must be staffed with men who have the necessary linguistic and scientific accomplishments, and that the study of foreign markets and of the nature of the foreign demand for goods shall be made a scientific study.

In Germany, besides the assistance of their complete Consular Reports and the help of carefully devised legislation and low export rates on railways, there are special institutes founded in connection with the Universities for the scientific study of the problem of international commerce. Private firms also associate themselves into export societies. Thus manufacturers, shippers and financialists interested say, in the Russian or South American trade, will club together to obtain information, support agents, and obtain facilities. Steps will probably be taken for a long time to come to prevent the re-establishment in Great Britain of that immense system of organized commercial espionage by Germans who took situations and appointments of all kinds here at reduced salaries, because they were partly supported by subsidies, to collect information and transmit it in weekly reports to their real employers in Germany.

In the main, however, we have to rely on bringing to bear scientific knowledge of all kinds upon the manufacture and distribution of goods and obtaining foreign markets for the same.

The subsidization of private or national scientific research by Government funds is, therefore, only a small part of the matter.

We need to bring the scientific method of collecting the facts and drawing inferences from them to bear upon all the commercial problems of obtaining the markets and securing custom for the manufactured article. In connection with this part of the subject reference should be made to the valuable series of addresses by Mr. T. C. Elder on behalf of the British Electrical and Allied Manufacturers Association (see *Electrical Industries*, March 1st, 8th, and 29th), and also to a recent book by Mr. D. N. Dunlop on *British Destiny*, in which the principles of scientific co-operation without destruction of true Individualism are well expounded. Some excellent pamphlets on the recapture and expansion of British Trade are also published by the International Correspondence Schools, Ltd., of Kingsway, London.

The importance of a true education in science is that it leads to love of accuracy as to facts, loyalty to scientific truth, unwearying labour in obtaining it, and care in the inferences derived from it. We have to cut ourselves adrift from all the past, its easy, self-satisfied mediocrity, dislike of trouble, and contempt for knowledge.

The first steps in this seem to be large reforms in education, and the second reforms in our system of party government in which the true requirements of our national life are subordinated to the efforts to retain political power in the hands of individuals, clans or parties. The only desirable form of Government is an aristocratic Government in the true and proper meaning of the term, viz., government by the most efficient and the best. The nation will have that Government when it demands it in sufficient earnest.

Discussion.

The **President** said that his present duty was to express to Dr. Fleming the thanks of the Council for his very valuable contribution to the Transactions of the Society, and to provide those present with the opportunity of expressing their appreciation of the address to which they had just listened.

Before putting the vote of thanks to the meeting he would like to make a few general remarks on the subject which had been so ably brought before them by Dr. Fleming. He thought the distinguishing characteristic of the British engineer was a somewhat exaggerated respect for the liberty of the individual. Politically, that was an excellent trait, but in matters of business we all suffered from competing with each other rather than joining forces to compete against rival nations. As he understood the paper its main point was to recommend the modification of our methods in that direction, and in his view the purpose of their meeting would be accomplished if they assisted, even to a small extent, in securing such an important result. Nevertheless, however desirable it might be to imitate certain aspects of the policy adopted by our enemies and rivals, he would strongly urge that we must carefully avoid being led to the extreme of accepting German methods as universally preferable to our own. As we had been wise enough to modify our political constitution from time to time to suit the exigencies of changed circumstances, so must engineers consider, not the adoption of an entirely new system, but the best way to modify that which experience had shown to be defective in the old system. He trusted that the discussion would prove that view to be shared by others.

He would ask the meeting to accord a very hearty vote of thanks to the author.

The vote of thanks was carried by acclamation.

Col. Crompton, who had been associated with the author in some of the early electrical developments, was naturally much interested in all that he to-day put forward in support of increased facilities for technical education. He thought, however, that the author was not fully aware of recent developments at the National Physical Laboratory, as many of the author's suggestions in regard to metallurgy had already been carried out, and plant of the character suggested had been put down and been at work for some time.

Personally, he thought that the present small demand for technical education arose from want of reasonable teaching in childhood. That in most families the majority of children are observant and naturally curious to know something about the things which they notice and feel, but owing to the ignorance of their parents and nurses their questions are rarely answered in a sufficiently intelligent manner to stimulate their natural desire for further knowledge of physical phenomena and the laws which govern them. He felt convinced that if the present generation of fathers and mothers and nurses had been sufficiently well-grounded in simple physical laws to be able to answer the questions of their ten-year-old children intelligently, the curiosity of these children to know more of the world in which they live would so develop that the majority of them would delight in further technical studies, so that instead of, as at present, only one out of a family of four asking for further technical knowledge, *i.e.*, to become an engineer, architect, doctor, chemist, metallurgist, etc., the proportions would be reversed, and three out of four would ask for further teaching. When this became the case, the great extension of technical education proposed by the author would be demanded from all our schools and educational establishments.

Up to the present the country had been ruled by a majority of men badly educated in the knowledge of physical laws of the world in which we live, and until this was altered and the majority became better educated in this knowledge, which ought to be known to everyone, we should not have that demand for further technical education which was universally desired by people who had acquired such knowledge. Under present conditions, both in society and in commercial circles, there was a feeling that the average man who settles down to business possesses knowledge superior in kind, and in nature, to that possessed by the technical man, who, as a preliminary to their technical education, must have acquired a reasonable knowledge of physical laws. If the average city man had been equally well grounded in the knowledge that all engineers, architects, surveyors, doctors, chemists, and metallurgists must possess before they can commence their real technical education, we should hear far less of valuable inventions made in England being starved in this country and developed in Germany. In the latter country those technically educated had established their position, so that their financial and business houses found it necessary to take their advice. It was this mutual assistance given by the technical men to the financial men of Germany which had organised the group bank system, which had been the most potent agent in the development of Germany, as a manufacturing nation. In Germany the inventor takes his ideas to the technical advisers of the group bank, and if the invention is considered promising that bank finds money for its development at reasonable terms ; whereas in the city of London the same inventor would have to run the risk of finding a financial man—a company promoter who would not touch any invention, however good, unless it brought high rates of profit to those who found the money. As was probably known to the many present, he personally had made considerable progress in the development of electrical science at the time when Germany had hardly started, and had had a thousand men at work when the Allegemeine Electricitals Gesellschaft had half that number. A few years later the position was reversed, the Allegemeine, owing to the group banks' aid, had extended itself on a gigantic scale, and had deprived English electrical manufacturers of most of their export trade.

Mr. Alfred Saxon said he was pleased that the subject of engineering and scientific research was receiving attention in this country. The lecturer had pointed out the importance of the subject to our national industries. Manchester had been somewhat active in the matter, particularly the Engineers' Club. The engineering section of the Manchester Chamber of Commerce had also met during the past week to discuss some draft resolutions with regard to British trade after the war, both resolutions presented beginning as follows :—" That, whilst fully recognising and appreciating the importance of and necessity for increased scientific industrial research and training," etc. This was a proof that commercial men now fully recoginsed the importance of research work.

The author had made a great point about Germany, but he (the speaker) thought that it was necessary to keep our eyes also upon the United States, because at the present time they were tending to secure a monopoly in the markets of the world, and were strengthening their industrial and financial position to the fullest extent. With regard to the Board of Education scheme, the Manchester Association of Engineers had taken advantage of the financial assistance afforded by that scheme in connection with the experiments on high-speed tool steel which were being carried on with the co-operation of the Manchester School of Technology. The experiments were in progress before the Board of Education scheme was placed before the Association, but the result of the grant by the Board of Education would be materially to assist the work. As to the carrying on of research work, he thought that associations such as the Society of Engineers, the Institution of Mechanical Engineers and the other engineering associations of the country were the very channels by which the work could be carried on in conjunction with the colleges and technical schools, and there were men connected with such associations who were engaged in the management of large engineering works who were prepared to spend time in assisting research workers. He thought that these associations which were not " out " for profit, like private enterprises, ought to be used by the Government.

With regard to the education and training of engineers, he would like to mention the advice of a well-known Manchester engineer, the late Sir William Bailey, which was to " cultivate the imagination." That to some extent bore out Col. Crompton's idea. He believed that boys and girls had their imaginative faculties in far better exercise than had adults. Sir William Bailey recommended that students and others should read such works as those of Jules Verne, so that they might have their creative and imaginative faculties stimulated. The growth of submarine and aerial navigation to its present state was, he felt sure, purely the outcome, in the first, place, of imagination.

He agreed with the author about the great waste of money in the educational system in this country, under which youths were not compelled to attend some kind of evening or continuation school after they had started work, and hoped that this would be remedied in the near future.

Professor Miles Walker said that there were many aspects of the question. Many of these had been very ably dealt with by Dr. Fleming. He (the speaker) proposed to confine himself to the research which ought to be carried out in connection with heavy machinery. The matter was one which required much consideration and the making of special provisions, because it was not one which could be carried out easily by a national laboratory. When one was dealing with heavy machinery and with manufactures which were being turned out in very large quantities, it was not easy to carry on experimental work efficiently in a national institution. He knew from experience that, in England, manufacturers had neglected to do experimenting when they had a big machine at their disposal. He would take as one example of the way in which this country had at one time got behind, viz., in the matter of electrical winding machinery. He might say that we were in a better position now than we were a few years ago, but it was true that a few years ago nearly all the big electrical winding engines of this country were of foreign manufacture. The reason simply was that the big manufacturers did not conduct experiments on a proper and extensive scale with their large machines, but they were content to go ahead building things as they always had done. It was necessary to see that arrangements were made to enable manufacturers to do more than they had done in the past. What were the difficulties ? The main duty of the manufacturers was to deliver the machines, to get them running, and to collect the money for them. He was afraid that in the past those were the main things to which the attention of the manufacturers was directed. If any suggestion was made that it would be well to delay the running of the machines, and to spend a small part of the hard-earned profits upon conducting experiments, it did not meet with any very great sympathy. Another difficulty was that the engineers employed by manufacturers were so busily engaged upon their routine work that very often they did not get the time in which to conduct experiments upon a proper scale. In addition to that, even if they had the inclination, they did not receive much sympathy. Another difficulty was that in big manufacturing firms certain instruments of precision were very often not available. That seemed to be a deplorable thing to say, but he knew it was the fact that very often experiments of an important character would be carried out if there were at hand some costly apparatus which was not for the moment available. He felt that, however much might be done in the way of establishing research laboratories, and however much might be done in the way of stimulating research after the War was over, this matter would still be one in which this country would be behind unless care was taken. It was not sufficient to convince manufacturers and the managers of big engineering works of the importance of research. He was sure that many of them were fully alive to its importance. Some of them were quite sympathetic in the matter. One of the main things which it was necessary to do was to establish, firmly, the determination to carry on experiments on a large scale. There was in the minds of managers a fleeting determination to see, when a machine had been finished, how it would do to change so and so, and to carry out some experiments by which some further advance could be obtained ; but, when it came to the rush of delivery and the rush of starting up, all that was forgotten. If funds could be allocated to the kind of work he had indicated; if the determination on the part of the manufacturer could be consummated; and if there could be a larger number of men employed in the big factories whose main energies were directed to experimenting, great advantage would result. It was necessary that there should be in the large factories men whose business was not merely to earn money, and not merely to turn out so many designs or so many specifications in a certain time, but to see what could be done in the way of improvements, and whose duty it would be to see that, when anything came along upon which experiments could be tried, those experiments would be tried. That would not be a difficult matter in large concerns where the profits were good enough to provide and to pay for such men, but for the smaller manufacturer it would not be an easy thing. The small manufacturer could hardly be expected to keep a paid experimental manager. He thought for that reason the great national institutions should have associated with them a number of men with the proper training, who could be lent to the smaller manufacturers. Those men would bring the very best mathematical, physical, and engineering knowledge to bear upon the problems which they had to tackle, and they would have the facilities which only the manufacturer could give. He was speaking only of that particular class of research which could be carried out in conjunction with the manufacturer. The universities, of course, could aid in the matter. The University of Manchester had done all that it could. It had been in fairly close touch with manufacturers, and it had been able to lend them experimenters and apparatus when they needed them, and some quite important discoveries or developments in apparatus had been the outcome.

Principal J. C. Maxwell Garnett congratulated the author on his exceedingly interesting paper and agreed with him very heartily when he said that the only way in which to secure the permanent pre-eminence of British industry was by changing the British attitude towards education and research. He thought that the author was absolutely right when he urged that there were two kinds of changes which were needed: First, it was necessary to change the attitude of the country towards the sort of knowledge which ought to be conveyed in schools and other places. It was, for example, necessary to get the centre of gravity of the whole curriculum nearer to natural science. And, secondly, it was necessary to teach people to *know how to do* things rather than merely to *know about* things. People were in danger of being ashamed of ignorance when what they ought to be ashamed of was incapacity.

One of the great difficulties in secondary education at the moment seemed to him directly connected with that fact. It was usual in a great many secondary schools to have six or seven separate subjects (forming part of some university local examination or matriculation examination) taught by six or seven separate teachers, so that the poor children had no form master or no form mistress—and that at a time when the formation of character was, perhaps, in its most critical stage. They ought to be taught by somebody who at any rate for half or, perhaps, for more than half of the week could give them his or her whole attention. When people were urging the need for the teaching of more natural science—and he heartily agreed that more natural science ought to be taught—they must not forget that character training (for which, in a day school, the form master is largely responsible) is more important than mere teaching, whether of natural science or any other matter. There was a danger that, in trying to get something good, they might sacrifice something better. Everybody ought to know some science. Every civil servant, for example, ought to be familiar with the elements of natural science ; but people were confusing the need for " science for all " with the need for men who possessed first-rate ability and had specialised in some branch of natural science to occupy certain important positions in the Civil Service.

As to continuation schools, he quite agreed with the author in hoping that all who left elementary schools to enter employment at the age of fourteen would attend a continuation school until they were at least seventeen or eighteen years of age. He would make instruction not merely vocational but " specific " ; that was vocational and social, preparing not only for a vocation in life, but for the whole life ; so that the student, understanding something of economics and history, might help to solve social problems from the inside.

Turning now to the question of organising industrial, and especially engineering, research, he would urge that while the Government could do a great deal by advising and assisting, and could go in turn for advice to the technical and professional societies, the initiative must come from the British firms themselves. That had been the principle upon which the Manchester proposals had been based. The money must largely be found by the firms. It would not do to give Government money if no money was coming from the people who were directly interested. He would like to read one or two extracts from the Report which the Engineers' Club of Manchester recently produced. A council of engineers had been established to carry out, as far as possible, the proposals made in the Report. All the largest engineering firms in the immediate Manchester area and almost all in the surrounding district had already joined this movement.

The Report began by saying " Your Committee is convinced that advantage can best be taken of the present opportunity by the formation of an Association :—

" On a non-trading and non-interference-with-prices basis. This Association should comprise British manufacturing concerns in all branches of Engineering, aim at the inclusion of every such concern, have a constitution giving it a legal status framed on broad principles, and possess an efficient and energetic management. Such an Association would speak with a powerful collective voice in matters with which Parliament was concerned, would assist the Government in questions connected with industry and commerce ; and would be entitled to representation on the governing bodies of universities and technical colleges."

The Report dealt with the activities of the proposed Association under the following heads :—

Intelligence (the collection, analysis and distribution of technical and commercial information).

Production, Inventions and Patents, Publicity, Finance, Education and Research, and Parliamentary.

The functions of the proposed Association in connection with Education and Research were as follows :—

1. To advise Government departments (Board of Education ; Home Office ; Civil Service Commission, etc.), local education authorities and the governing bodies of schools, colleges and universities in regard to the education of engineers of all grades ; and to advise members in regard to the education of their employees ; and in particular :—

(a) To nominate representatives of the Association to serve upon the governing bodies—or upon advisory committees of the governing bodies—of universities and technical colleges of university rank.

(b) To advocate :—

  (i.) The establishment of new schools and colleges where required ;

  (ii.) The provision of suitable courses in existing schools, colleges, and universities, and especially the provision in certain universities of technical-commercial courses which, when combined with practical experience, shall prepare future commercial representatives of engineering firms to understand their customers' interests, the conditions and languages of the country in which they trade, the merits and uses of their goods, so that they may undertake successfully the selling part of engineering business ;

(iii.) The co-ordination of all schools and colleges in which engineers are educated ; and, in order that this co-ordination may be effected and the system thus formed thoroughly democratic ;

(iv.) The establishment of an adequate system of scholarships and bursaries so as to secure that no person, who, if he passed through a certain course, would be needed and demanded to fill some place in the engineering industry, should be prevented from taking that course for want of a scholarship or maintenance allowance.

(c) To encourage members in each area to establish, in co-operation with the Education Authorities of the district, a scheme for the advancement of apprentices ; and to urge every member to provide at least such minimum means for encouraging apprentices as are prescribed by the scheme in force in their district.

2. To encourage research in the following among other ways :—

(a) By making recommendations to the Finance Committee in regard to money grants to universities, technical colleges of university rank, and other institutions.

(b) By moving the Parliamentary Committee to secure adequate government grants for purposes of industrial research.

(c) By undertaking, and recommending the financing of, particular researches in co-operation with universities and colleges.

(d) By advising members in regard to particular researches or tests which they may wish to undertake, or to have undertaken on their behalf, in the research or testing laboratories of some central university or college.

(e) By developing co-operation between engineering firms on the one hand and universities and technical colleges on the other as recommended in the section on Production so as to establish such " Schools of Thought " as exist in the research departments of great continental and American engineering firms, but cannot be fostered in the comparatively small establishments (and smaller research departments) of most British engineering firms."

The researches on cutting tools to which Mr. Saxon had referred and which had been going on in his (the speaker's) college—the Manchester School of Technology—for some time, afforded an excellent example of the co-operation between manufacturers and colleges contemplated in the last sub-section. He hoped that, while the provision of new public laboratories for industrial research would not be neglected when the necessity for them arose, such laboratories would not be established until the resources of the existing universities and colleges had been exhausted. The use of college laboratories for this purpose was accompanied by a very valuable by-product in the shape of the educational influence of those who directed such researches. Any innate capacity for an original research possessed by students would best be fostered by placing them under the direction of professors who were themselves originating and carrying out important researches. It was, moreover, the man who was doing original work in his subject who most inspired his students with an interest in their studies and with a love for research.

Mr. A. P. M. Fleming said that there were three points in the paper which he wished to discuss from the point of view of the manufacturer. They were industrial research, technical education of engineering students, and the industrial education of mechanics. He did not think that the author had indicated forcibly enough the point which Principal Garnett had made, namely, that the crux of the problem lay with the manufacturer. To the manufacturer industrial research was simply a search for new knowledge, and if it seemed well to him he might use that knowledge in the development of new apparatus in making it cheaper and in improving it. If he was not so minded, or if he was not alert enough to make use of such knowledge, then from the utilitarian point of view the value of the research was lost. So the manufacturer was either an obstacle or a driving force as far as research was concerned. He was afraid that at the moment one had to write off the manufacturer as rather an obstacle. Often he had not received a scientific education, and consequently did not appreciate the need of science in industry, and was conservative about investing money without an obvious and immediate return. There were large numbers of young engineers technically educated who were entering industry, but it would be years before the higher levels of employment could be considered to be so permeated with scientifically trained men as automatically to remove the obstacle. How was the obstructive force to be converted into a driving force ? It could be done only by approaching the manufacturer and appealing to his self-interest. Apart from the means taken by associations such as that Principal Garnett had described, no channel by which the employer and the manufacturer could be educated should be neglected. He would suggest that the technical and daily press and the various engineering, scientific and trade institutions might be more fully utilised to bring home to the manufacturer the economic importance of the weapon which research afforded as a means of competing with the foreigner. Through the channels afforded by the press might be shown the really wonderful work and great progress which was being made at present by foreign competitors who were making full use of research.

The most efficient way of applying research in industry was to have the research laboratory situated in the works. There were many examples, particularly on the Continent and in America, which proved that statement up to the hilt. Wherever a research laboratory was instituted in connection with a works there were three distinct stages through which research work usually developed. In the first instance, it dealt with the scientific elimination of manufacturing troubles. The second stage was its application in the improvement of materials, tools and processes. Lastly, there was the pure science investigation, which had no immediate commercial object, but which might result in discoveries leading eventually to priority in some new industrial developments.

Comparatively small firms having only a small amount of capital could not be expected to devote much attention to research. Fortunately, manufacturers were becoming sufficiently broad-minded to discountenance secret processes to a large extent, and they recognised that there were tools and materials common to all, and that they could co-operate in research which would improve those things to their mutual advantage. The time had never been so ripe for such co-operation. It was necessary to consider not merely engineering, but industry as a whole, since all industries were so interdependent. The last stage of all, the pure science work, must always be independent of an individual industry. Scientific investigations might lead to possible applications in any one, or even a number of industries. Viewing the matter from a manufacturer's standpoint, he thought that one might expect to see a tendency for research laboratories to culminate in a central laboratory on account of economy and generally of more efficient running. Such an arrangement would afford the best means for the collection and distribution of scientific data to industry, and would also be the best means of collecting data in relation to any particular research.

He recently investigated a large number of the industrial laboratories for research work in the United States. There were upwards of fifty such laboratories connected with individual corporations, each requiring for its maintenance from £10,000 to £100,000 a year. With the total sum of money expended by these corporations, together with that spent in connection with the Department of Argiculture, there would be enough money to deal with the research required for the whole of the industries in this country, if arranged on a centralised plan. The great point that one should start with in any research scheme was the development of the latent driving force which existed amongst manufacturers. That was the point at which the Manchester campaign had started.

The author's suggested sandwich system for teaching engineering students had excellent features. From a purely manufacturing point of view, however, it was very desirable that a great part of the practical training should come after the completed college course. He would like to suggest one addition to the syllabus proposed by the author. Many students of engineering ultimately became absorbed in manufacturing concerns, and one might reasonably expect them to be in a measure equipped for such work. Now, the whole object of manufacturing was to produce efficiently, but, unfortunately, engineering students, as turned out at the present time, had little notion of the science of manufacture, and no appreciation of the function of organisation. A great deal of good, he thought, would be done by giving the students some training in the economics of manufacture and in the principles of works organisation. Much was being done in this direction by certain institutions, such as the Municipal School of Technology, Manchester, Sheffield University, and institutions in London. Manufacture was at the present time reduced to a science, and it was in technical schools that one expected its fundamental features to be taught. There was an increasing need in engineering works for scientifically trained young men who could take responsible positions in the works organisation.

Probably 90 per cent. of the youths in engineering works, who entered at the age of fourteen or fifteen, would be manual workers all their lives despite the fact that many of them attended evening continuation schools. The education which should be imparted to those youths should be such as to make them the most efficient workers possible. Then select the best of them as they showed themselves able and willing to rise to higher positions, and educate them accordingly ; but it was a mistake to try to educate all for higher positions. The educationalist had done as much as could be expected of him, and the manufacturers ought now to shoulder the problem and determine the character of education that should be given to such youths. He believed that much of the education could be imparted at schools provided in the works, and that in this connection there was a very important secondary benefit to be gained by the close connection between the employer or his representative and the juvenile worker.

Mr. John Dewrance said it seemed to him that it was necessary, continually, to winnow out the chaff from the corn in the course of the education of young people. Nearly all college teaching was lacking in the element of production to time. It was not sufficient to teach a boy how to produce a certain article, but he must be taught that the article had to be produced in a certain space of time before he had really learnt thoroughly. Many factories preferred a boy straight from school to a boy who had been through a technical college. With regard to the necessity for extending research to the large operations of machinery, that was a tall order. The Government were facing that question. The War had caused men to combine together under the Government in order to carry out investigations which had never been made before in this country. Some time ago he visited a factory and saw the first successful result of £100,000 spent in experiment.

Manufacturers will require to be educated, because at the present time they always felt disposed to keep secret the results of their experiments. That disposition was not altogether without justification. One great laboratory spent an enormous amount of thought and care in producing a formula for the production of light metals, and up to the present the only people who had benefited by that research had been the Germans. At present the research was being carried out in secret. Some manufacturers had the idea that this country gave away too much to its foreign competitors. We are too much inclined to believe that our own scientific people are inferior to the German scientists. He thought that the reason why the Germans had forged ahead so much was that they had actually produced a brand new idea in commerce. The German Government, through the banks and through the enormous concerns they controlled, actually was working at a system of socialism which meant that the Government itself was rapidly becoming the only employer, because there were very few concerns of any magnitude in Germany which were not immediately the property of the banks which were the property of the Government. If that was to be the future of commerce, each particular Government would be an exclusive employer and individual employers, and individualism generally would suffer a great setback.

Lord Headley said that as engineers they were nothing if not constructive, but it struck him that we were faced by a very considerable difficulty in the matter of changing the curriculum of public schools, because classical training was a great feature in the training of British youth, and it was questionable whether it would be advisable to do away with it altogether. He was not a classical man, but he knew a little of Latin and Greek, and he had found them of great use, especially in the study of modern languages. But he thought that too much attention was devoted at public schools to the study of the classics. The classics would never help us to build aeroplanes, for instance. He thought that we did not give sufficient attention to the study of science.

Recently he had learned the meaning of the word " Kulture." It contained the German idea of civilisation. God forbid that the German idea should take hold of this country in such a way that we should work at science in order to gain the mastery of the world by foul means. What we really needed was to take every advantage of our opportunities of encouraging invention and new scientific ideas. He had been glad to hear from some of the speakers that great efforts were being made to encourage and foster scientific training in many directions. We heard a good deal about the intelligence of Germans, and they were, no doubt, intelligent, but he did not think that they were more so than the British. Their intelligence was chiefly shown by their methodical thoroughness and by working at ideas (which very often they had obtained elsewhere), with greater determination possibly than the British displayed. There was no reason whatever for thinking that the German mind was superior to the British mind. Sir Isaac Newton, for instance, was not bad at science, and Shakespeare in his own line would take a lot of beating. Then there were Jenner, Harvey, Lister, Darwin and others. Men like those whom he had named showed that the superiority of the German mind was only imaginary. As he had said, it was due to thoroughness and perseverance rather than to any special inventive ability.

He was convinced that State controlled intelligence was bound, sooner or later, to lead to a kind of mental atrophy. He thought that always to be telling a person exactly what groove to go in, and how to go, created a tendency to do away with originality and prevented discoveries. In Germany every man from the time that he was born was more or less " verboten." If he threw a cigar end down on the road it was verboten. If he tried to pick it up it was verboten, because it was the scavenger's business to do it. When the scavenger got it he must not smoke it, but had to put it into the destructor, and any other way of disposing of the cigar end was entirely contrary to the law, and, therefore, verboten. He thought that it was time to take advantage of the lesson learned from the Huns. It must be possible to give rein to the spirit of genius without running to the extreme of state directed study which was paralyzing to genius.

With regard to bringing up three out of four sons as engineers, as Colonel Crompton had advised, he (Lord Headley) might mention that he had four sons who, unfortunately, or perhaps fortunately, had very different leanings and tastes. One was rather inclined to be literary ; another had a bent in the direction of mechanical engineering ; the third was very artistic and musical, and the fourth was inclined to be destructive. He would sooner see them engineers than anything in the world, but how could boys make a success of engineering if they did not show any leaning towards it ? Therefore, he did not quite know how what Colonel Crompton had suggested in that respect could be accomplished in all cases, since it would be obviously unwise to make a boy an engineer unless he showed a special aptitude. Colonel Crompton had said that mothers, sisters, and nursemaids ought to be instructed in scientific matters for the benefit of the children in earliest infancy. He (the speaker) thought that it would be a very good thing indeed to inculcate the love of natural science in everyone. Adults ought to be able to answer children's questions in an intelligent manner and should make a point of doing so. He did not believe in telling children a lot of fairy tales about the facts and realities of life. They all knew about the Bishop and the question " How many legs has a caterpillar got ? " Nobody knew except a little boy who said, " I know. It has six. I have counted them."

Dr. Hele Shaw, who was only able to arrive late, said that he had come not to speak but to show his sympathy with the reader of the paper in the efforts that he was making. He hoped that he would be allowed to contribute to the discussion in writing as he had not had time to prepare a speech. He noticed that the author referred to Professor Coker, and he would like to mention an episode which occurred recently, because it illustrated in a remarkable way the sort of thing that now happened in scientifical research in relation to industry. At the Royal Institution recently Professor Coker gave a most interesting lecture on his new method of applying polarised light to the investigation of stresses. All engineers knew that the form of eyebolt even for the largest ties up to six inches or more was a circle united to the tie rod in a symmetrical manner by nicely rounded off curves. The stresses in such a design were submitted by the new method to the test of polarised light which showed that these stresses were of the most severe and even appalling nature, and that the beautiful appearance of the design was a delusion and a snare. The Professor then showed by his method that the eyebolt, largely adopted in America, which consisted of a flat elongation with rounded ends tapering off, though ugly, was better, but not good. He then showed finally something in the shape of a long oval with a hole right in the middle. It looked something like a fish with equal slope at both ends. It was a rather weird design and to the engineer a startling departure from ordinary practice. The Professor then showed, by his method, that the stresses were perfectly distributed and that this strange looking object was the really perfect form for an eyebolt. Now, if the Professor had published this, it is almost certain that no notice would have been taken of his design except to regard it as a professional freak..

Almost immediately after the meeting he (the speaker) happened to meet Dr. William H. Maw, the Editor of *Engineering*, and sketched the new eyebolt that Professor Coker had shown. Dr. Maw said, " That is the exact end of the eyes for large tie rods adopted by the biggest bridge building company of America and at which they had arrived after spending large sums of money to achieve. The result, experimentally, and which when arrived at, this engineering firm did not know any method of theoretically investigating so as to help them in other similar designs." He (Dr. Hele Shaw) wrote to Professor Coker and said, " You must have got that design from somewhere. I thought I understood you to say that you arrived at it by your own experiments." The Professor said, " So I did. I have never heard of the American design or anything of the kind before."

The meeting could easily deduce the moral from the anecdote, and it formed a striking example of the need of closer relations between the practical man and the scientific investigator, and illustrated the great benefits which would result from the more complete organization of research and what might result if professors and manufacturing engineers could collaborate more closely in their work.

Colonel C. E. Cassal said that Dr. Fleming's admirable paper was full of valuable suggestions. He (the speaker) represented a body of people who were far less organised than were engineers, namely, chemists. In this country the profession of chemistry was in a state of well-nigh hopeless disorganisation and could not for a moment be compared with the engineering profession in regard to capacity for managing its own affairs. The bodies representing the chemical profession never did and had never done what the Institution of Civil Engineers, the Institution of Mechanical Engineers, and the Society of Engineers always did, namely, invite members of other professions to attend their meetings and to take part in the discussions.

Until chemists became less narrow-minded and more ready to appreciate and absorb the ideas of other people he was afraid that they would continue to be very much in the background. There should be a very close connection between the engineer and the chemist. The chemist could be of great value to the engineer, and the engineer could be of great value to the chemist, but in this country one could count upon the fingers of one hand the men who could be described as capable of dealing, effectively, with problems involving both chemistry and engineering. Very few chemists, indeed, had given any attention to engineering problems or knew enough of the elements of engineering to carry out chemical schemes involving such knowledge. He admitted that the Germans possessed a great faculty for plodding of an inferior kind, but he agreed with Lord Headley and other speakers that it was a delusion to attribute to them superiority in science. Certainly for the last fifty or sixty years, Germany had produced nothing brilliant in any branch of science. They certainly plodded strenuously at the spade-work and scavenging required for working out ideas which they had stolen from other people, but for the last fifty years at least they had produced nothing brilliant in science or anything that would compare with the work of the French, English, Italians, Swedes, and Russians. He thought, therefore, that there was no need to be afraid of the competition of the Germans in the higher intellectual regions, but there was need to fear their unscrupulousness, their dishonesty, and their practice of stealing anything upon which they could lay their hands.

In this country we needed some sort of sane constructive policy to put ourselves right. We had gone very far in wrong directions. Our system of education and our political system had militated against our working successfully for a position that would enable us to stand against the organised villainy of the Teuton. We had a system of education which certainly did not develop scientific thought or a desire to work at scientific subjects. We had a political system which resulted in placing the direction of the nation's affairs in the hands of persons whose ignorance of science was absolutely monumental. And yet those persons undertook the direction of large industrial concerns the success of which was absolutely necessary for the defence of the country and victory in the war. As Dr. Fleming had very truly said, our educational methods, even in most branches of science, were far too " bookish " and academic.

The college laboratory might be a suitable place in which to carry out certain forms of research, but technological research could not be successfully conducted in colleges. There was absolutely no sympathy or proper connection between the college laboratory and the works laboratory, and the result was that a man solely trained in a college laboratory and finding himself in some works where a knowledge of technology was essential was completely at sea. The chemical profession was divided, roughly, into two camps, the camp of the schoolmaster or academic professor, and the camp of the professional chemist. Until that was altered, we should continue to be in the position of difficulty in which we were at present. He wished, before concluding, to refer to the patent laws. He did not know whether it had ever occurred to anybody that one of the reasons for the comparative failure of the attempts to make British dye was that, in regard to the granting of patents, we had been as foolish as we had been in other directions. We had allowed the Teuton to come to England and to steal our ideas and to file specifications on which patents were granted in which in a number of cases certain essential points were carefully left out so as absolutely to prevent the patent from being successfully worked except in Germany. The trick in question was played in regard to matters other than those connected with the dye industry, and the facts stated afforded an illustration of the stupidity of our system.

It might be desirable, as Colonel Crompton had suggested, that even nursemaids should receive some scientific education to enable them to assist in the education of children. At any rate he felt very strongly that we had a great and very difficult task in front of us, and that it would require the best brains of the nation to consider the methods to be employed in order to bring our industries up to the standards that they ought to reach. He believed that the war had come in time to save us from the destruction towards which we were hurrying under the ridiculous systems which had been followed in the management of the industries and in the government of the country.

Dr. W. Eccles said that he would like to support the author in urging that the present was an epoch when the relations of pure science to industrial research had a chance of being put upon a more satisfactory basis than ever before. Hitherto the relations between science and industrial research in this country had been sporadic, accidental, and go-as-you-please. In the future they ought to be conscious and methodical. He hoped that Professor Fleming would continue to " peg away," and so keep in full view the fact that the present was the time for making efforts at producing co-ordination. In this he would be rendering very considerable national service. It might be said that what was really needed was the formation and development of public opinion with regard to these matters. It was necessary that public opinion of the proper kind should be stimulated and developed, so that influence might be brought to bear upon Government circles and all those possessing any measure of authority in industry. Such a procedure would be the English method of work as contrasted with the German method ; the German method, he supposed, would be the establishment of a bureau to bring about the desired result by open or secret coercion. He thought that the best method to encourage the prompt application of new scientific discovery in England would be to mould public opinion by the holding of such meetings as the present meeting and by calling attention in that way to the opportunity, and the necessity, which was now before the country. Everybody in this country was now realising that if a nation neglected to apply science to steel and guns and ships and armour and explosives and aircraft, then that nation by neglecting these applications of science would go to the wall, or would at any rate take a very subordinate place among the powers. As the application of science was recognised as so necessary in the present war, it ought to be easy to convince the public that it was equally necessary in the industrial war which was to follow.

Mr. Burnard Geen, A.M.I.C.E., wrote saying it was regrettable that in the minds of a large section of the community an engineer is considered to be " something of a mathematician," but very little else.

He did not think that it could be disputed that the earning capacity of a given standard of brain in this country was lower in engineering than in many other callings, and this was largely, if not entirely, the fault of engineers themselves, which they could and ought to rectify.

The amount of recognition in the form of State honours falling to the engineering profession, too, was low, out of all proportion to the inestimable value of the services rendered to the State by Engineers, and one only had to reflect for a moment to realise how nearly all commercial advancement and prosperity was built upon the solid foundation of engineering skill and knowledge. A more liberal recognition of the value of the services rendered by engineers to the state could not fail to have an encouraging effect upon engineering effort. One of the gravest disadvantages under which the engineering profession labours was the deficient education of the average professional engineer in the direction of business training. Be the engineer ever so skilled and wise in his knowledge and application of the laws of nature, how was he to bring conviction to the minds of those in financial circles (upon whose collaboration he is dependent) to encourage them to carry out his conception and ideas unless he was able to speak to them in terms and in a language which they understood ?

It might be that to the mind of the trained scientist it was objectionable and difficult to judge the value of his labours from a standard of pounds, shillings and pence ; but as this was the standard from which the world of commerce does and must judge it, and as it was chiefly for the world of commerce that he worked and from whom he received his support, it would appear to be fundamental that he should learn to view his work from the commercial standpoint, and be able to present his ideas in a form easily understood by the financial mind.

Engineering colleges were not, perhaps, the best means of supplying the deficiency, but the suggestion that engineering students should receive business training as part of their necessary experience was one which, if acted upon, could not fail to produce good results; and he would venture to predict that whenever an elementary business training was part of the mental equipment of every professional engineer, the word " engineer " will possess an entirely different significance, and the standing of the engineer in the business world will be considerably raised.

Mr. Geo. Watson wrote saying that in his opinion Dr. Fleming's survey of the relation of science to engineering, especially in connection with scientific research and education, was worthy of the attention of the whole engineering body in this country, and that the first and most pressing question was that of finance. If in this country we had capital in an available form for the proper development of engineering undertakings it is certain that money would be found, as in America, for the endowment of the technical colleges and schools for carrying on research. All that was required was to mobilise the national credit for the victories of peace just as it has been mobilised for the war.

He thought Dr. Fleming was perfectly right in laying stress on the necessity of research work being done in technical colleges, as there was no doubt that the effect on the education of the students of taking part in useful work of this character was highly favourable, and in many cases gave them the bent for their life's work.

As was pointed out so forcibly by Col. Crompton, the banking system controlled and regulated by the Government in Germany had been used during recent years with overpowering effect to further engineering interests in that country. Again and again large orders have been secured by the Germans for work which had been initiated by our people, simply through the credit facilities and the manufacturing advantages which they were able to obtain.

The Deutsche Bank, with its huge staff of experts, its connections and ramifications in every branch of engineering and in all other industries, its intimate relations with its own Government, and all the German Government agents abroad, was the greatest and most striking example of this German method.

In the United States they had an enormous amount of capital in the hands of a few competent men, who use it with the greatest enterprise and promptitude when opportunity offers, whether to create up-to-date works and factories, with every possible improvement for the attraction of the best labour and for production at the lowest cost, or for financing undertakings abroad which call for American machinery and material.

Our condition in the matter of patents is comparable to the state of things which would exist in the United States if their Government, instead of having one patent law for the whole of the States, had a separate patent law for each separate State, with huge and varying fees in each, instead of the present absolutely simple, final, and satisfactory charge of £7 down, which they make for the best patent searches, reports, and system of registration in the world, and seventeen years of genuine protection.

If we could have a similar patent law in this country, extended by arrangement with the colonies so as to cover not only Great Britain and Ireland, but all the British possessions as well at the same time, the gain to the Empire would be enormous.

No doubt there are some disadvantages to the multiplication of patents, but this would all be met satisfactorily and fully by having a real compulsory licence clause providing for a percentage royalty on the selling price of the article to be paid to the inventor by any manufacturer who wishes to take up the patent. Such a provision would remove all obstacles to trading, and would at the same time enable the patentee to draw a revenue from royalties for any article that was really worth protecting.

Mr. Watson would extend the life of a patent to twenty years and fix all royalties at 5%, 2% to go to the State, and 3% to the inventor, and would throw the duty of protecting the invention on the State.

Mr. A. T. Walmisley, M.Inst.C.E. (Lecturer on Waterways, Harbours and Docks, University College), wrote saying that the invitation to add a few remarks to the discussion upon Dr. Fleming's paper afforded him the opportunity to express his appreciation of his kindness in giving us the benefit of his experience as a teacher of electrical engineering coupled with scientific work. The foundation of all success in a profession lies in a preliminary good general education. Thus, "classics" developes ideals, "mathematics" the power of thought, and "science" the habit of observation, while "drawing," which might be described as the language of engineering, emphasises the value of accuracy. Mathematics is an absolute necessity for success, and its study and application involve thought. Even graphical methods for arriving at the distribution of stresses in a structure need mathematical work to prove their accuracy. He agreed with Dr. Fleming's remarks upon workshop practice, but considered that unless an engineer intended to spend his time as a manufacturer of engineering material, workshop practice is no substitute for the mathematical training. Investigations based upon reliable data are to be encouraged with a view to promote research, but research will not earn a livelihood unless followed by manufacturing development. Nevertheless no educational course is complete which omits research. Its prosecution is the practical study of the laboratory and workshop.

REPLY.

Dr. J. A. Fleming in his written reply stated that he desired, in the first place to place on record his thanks to the President, Council, and Members of the Society of Engineers for the privilege he had enjoyed of putting his views before them on the matter under consideration. He felt gratified that the paper had been the means of eliciting the opinions, orally and in writing, of so many eminent engineers on this subject. In ranging over such a considerable area of thought and experience, it was only to be expected that differences of opinion would reveal themselves, yet, nevertheless, there had been very great unanimity on fundamental points at issue. He agreed with Colonel Crompton that the foundations for an interest in scientific work must be laid in an improved general elementary education. The majority of children naturally exhibited an intelligent interest in things, and in constructive work and experiments ; but these nascent qualities were checked and hindered by the stupidity of adults who could not answer the child's questions and would not take the trouble to learn. The crying fault of elementary education as at present administered by the State is that it lays far greater stress on words than on things. In public school education the excessive attention paid to the grammars of two dead languages yielded no result at all proportionate to the time and expense spent over it. The proper mind training could be secured by suitable teaching in modern languages and science. Since the discussion on this paper had taken place an important conference, convened by the Committee on Neglect of Science, had been held in the rooms of the Linnean Society under the Chairmanship of Lord Rayleigh, to urge upon the Government the necessity for giving greater weight to scientific subjects in the Home, Indian, and Colonial Civil Service examinations and in the entrance examination to Sandhurst. If this recommendation is acted upon it will immediately put pressure upon the Public Schools to reform their curricula.

Another reform which seems desirable is to revise the subjects of examination for University entrance scholarships. At present classics obtain the lion's share in these emoluments. If on the other hand scientific subjects had greater influence on the results, another powerful lever would be brought to bear on the Public Schools to compel improvements. The effect of these reforms would be that we should have a better chance of sifting out and encouraging scientific and inventive ability in the rising generation. Our higher technical education would then also start from a more advantageous platform. It must be remembered that the whole object of the higher education should be to produce men who had originative faculties and initiative, and not merely literary or scientific pundits with only profound knowledge of what others had done.

He agreed with Colonel Crompton and others as to the superior originative faculty of the British intellect as compared with the German ; but to bring about practical results this had to be supplemented by hard systematic work and organizing ability ; and it is in this latter respect that we seem deficient or at any rate have not brought it to bear sufficiently on the problems of scientific research and industry. As regards pure research, he (Dr. Fleming) was strongly of opinion that the only right action for the Government was to bestow money grants upon learned societies, universities and research institutions or individual workers and leave them to expend it as they think fit, but not to meddle with details. As regards the technical research it must be left to be settled by the manufacturers, but the Government could and should maintain at a high level of efficiency Institutions such as the National Physical Laboratory for standardizing purposes.

It is the engineering firms and manufacturers who alone know the really practical problems which require solution. If they are properly organized and can draw on the universities and technical colleges for men trained in research methods then these firms can and should, themselves, do the work and not wait for, or depend upon, Government committees. A great part of this research must necessarily be secret unless it is to benefit our foreign and enemy trade rivals as much as ourselves. The means by which this self organization can be effected is through the technical institutions and engineering and trade associations.

Mr. A. P. M. Fleming has pointed out in his valuable remarks that the United States, quite as much as Germany, is becoming a formidable competitor and has and is organizing research institutions in connection with engineering works on a large scale. Professor Miles Walker has shown what heavy preliminary expenditure is sometimes required in the solution of some engineering problems. It is manifestly impossible for small engineering firms to undertake much of this work, but the association of a number of such firms would enable research work on a large scale to be undertaken, and undertaken with the secrecy necessary to benefit only themselves and not foreign rivals.

We have, therefore, in the first place to train the men who have faculties for research work and then to place them at the disposal of manufacturers who will in their own way undertake the solution of problems which are necessary for their commercial purposes. It is, therefore, extremely necessary that practical engineers should take more interest than they have so far done in the work, facilities, teaching and curricula of our technical colleges, and engineering faculties in the universities. The manufacturers have the greatest interest in seeing that the products turned out from these teaching institutions in the shape of students are useful products. The manufacturing engineers should, therefore, take an interest in providing apparatus and plant in these colleges, not for the purposes of self advertisement but with the disinterested object of placing really practical appliances at disposal for teaching purposes. They should also offer positions and opportunities to graduate students as improvers or probationers so that those with abilities may have a chance to show it and gain permanent positions on the staff. The manufacturers have to realize that it is only by taking a personal interest in the work of technical colleges that they will be able to draw upon them for men trained in the right way and on practical lines for the work of research.

At the present moment the output of the colleges consists too much of examinees with book work knowledge, and the essential reforms in the character of the teaching and nature of the examination tests can be brought about only by a closer co-operation between those who train the students and those who are to use them when they are trained.

We have then, above all things, to create in the minds of practical manufacturing or constructive engineers a stronger belief in the commercial value of scientifically conducted research. We cannot afford to sit still and " Wait and See " what other nations are doing.

It is, therefore, very satisfactory to hear from Principal Maxwell Garnett in his interesting speech that serious steps are being taken by numerous important engineering firms in and round Manchester to carry into effect these ideas by the formation of an association on a non-trading basis but which will have as its chief object to bring about the reforms above suggested. He (Dr. Fleming) was strongly of opinion that far more would be done by powerful voluntary organizations of this kind than by any Government committees. The result of this dreadful war has, however, been to give us " furiously to think " as the French say, and it is certain that, now we are awake to the realities of the position, British engineers and chemists will make haste to organize themselves and join hands with educationalists to reform from top to bottom the teaching and training of our younger generations.

Such discussions as the present serve, therefore, a useful purpose in giving an opportunity for the expression of opinion, and in conclusion he begged to thank all those who have joined in this Conference for the support and approval of his suggestions, and in particular the President, Mr. Percy Griffith, for his kind remarks and vote of thanks.

CONCRETE & REINFORCED CONCRETE.

By H. M. Wilson.

Note.—There are several student engineering societies affiliated to this Society, one of these being the Crystal Palace Engineering Society. On March 7th, last, Mr. H. M. Wilson, a son of Mr. Maurice Wilson, President of the old Society of Engineers in 1906, read a paper before the Crystal Palace Engineering Society for which he was awarded the premium for the best paper read before that Society during the year. The third part of the paper has since been partly re-written. Half the paper is printed below, and the second moiety will appear in our next number.

In dealing with this subject the Author proposes to divide the paper up into three parts.

These three parts will consist of :—

1. Cement.
2. Concrete.
3. Reinforced Concrete.

CEMENT.

It is hardly necessary for the Author to lay stress on the fact that the great essential for the manufacture and success of a good, sound, and strong concrete is that high-class cement be utilized in its manufacture.

There are many discriminations between a good and bad cement and the Author includes seven tests, all easily made and which will settle whether the cement under examination is good or inferior.

These seven tests are for :—

1. Soundness.
2. Fineness.
3. Setting.
4. Purity.
5. Tensile Strength.
6. Quantity of Magnesia.
7. Quantity of Sulphuric Anhydride.

The Author proposes to deal with each of these aspects in turn before proceeding with the subject.

Soundness.—If a cement is sound it will not go to pieces on the work. Consequently, testing for soundness is of the greatest importance and is indeed, in some cases, the only test necessary to prove whether the cement in question is reliable or not.

The test for soundness is as follows :—

Take about eight ounces of the cement to be tested and knead it for one minute and a half with a sufficient quantity of water to produce a thick paste like putty. Take three pieces of glass about four inches square, and put some of the paste on to each piece, making it into a pat about three inches in diameter and tapering from a thickness of half an inch at the centre to a thin edge. Leave the pats exposed to the air for the next twenty four hours. Keep one slide in the air for a period of twenty-eight days. Submerge the second pat in water for a corresponding period, and place the third in a loosely closed vessel over boiling water for a period of five hours. If any of these pats show radial cracks after being exposed to the above conditions, or curl or crumble, or change colour, then the cement must be rejected as being of an unsound nature.

It may happen that the cement is required for use at once, in which case the twenty-eight days' test cannot be employed. In such a case the steam test alone will be sufficient if the cement under investigation is none other than Portland cement, but natural cements should be subjected only to the water and air tests and not to the steam test.

Disintegration or crumbling of work in Portland cement properly mixed and laid, is usually due to an excess of lime in a form which can be attacked by the elements. This may come about in two ways : (1) By using too high a proportionate of lime in the raw materials from which the cement is made, or (2) by underburning the cement. Disintegration may also be caused by too high a percentage of magnesia, but this takes far longer to produce cracks than the former cause, generally taking a number of years to produce any effect.

It must not be thought that all cracks which appear on cement pats are caused by unsoundness. Expansion cracks which disclose an unsound cement must be distinguished from shrinkage cracks, caused by the cement shrinking in setting. Hair cracks also appear at times on pats, and are caused by an excessive amount of water being used in mixing the cement.

A faulty cement after two or three days' exposure to the air, or after two or three days' immersion in water, or after an hour or so under the steam test, will probably show cracks.

The blotching of a cement pat usually shows that the cement is adulterated or else that it has been underburnt. If this occurs widely, then the cement should be rejected on those grounds alone. Shrinkage cracks are generally due to the use of too wet a mixture or to too quick drying out. Consequently shrinkage cracks are simply due to the careless manipulation of the cement in making the pats, and are, therefore, no signs of a faulty cement. The radial cracks of disintegration then are the signs to be looked for most in cement pat tests, and always indicate a bad cement, which must be rejected on these symptoms.

Fineness.—The finer a cement is the higher is its value. Consequently the quality of a cement can be told by its fineness. To test this properly, take five ounces of cement and pass it through a hundred mesh sieve. Not more than half an ounce should be left in the sieve, that is to say ten per cent.

Setting.—Unless a cement sets after the right length of time has elapsed it is a great nuisance. A quick setting cement is difficult to manipulate on work, and a slow setting cement is a great waster of time, as it delays the removal of forms. In order to test cement to see whether it sets at the right time or not, proceed as follows :—

Make a pat of cement similar to the ones previously described. Two needles are then taken, one being one twelfth of an inch in diameter and loaded to weigh ¼ lb. ; the other being one twenty-fourth of an inch diameter and loaded to weigh 1 lb. The pat of cement must not be able to bear the weight of the lighter needle until thirty minutes have elapsed since it was mixed, and it must be able to bear the heavier needle in less than ten hours. A mortar or concrete has attained its final set when it is able to support the pressure of the thumb without indenting the cement.

Purity.—To test the purity of a cement the following apparatus is required. A bottle of hydrochloric acid, two shallow white dishes or two ½ in.test tubes, a glass rod and a pair of rubber gloves, which are necessary to protect the hands from the acid. Put in a dish or tube as much cement as can be put on a sixpenny bit, moisten it with half a teaspoonful of water and cover it with hydrochloric acid poured slowly on to the cement while stirring it with a glass rod. Pure Portland cement will slightly effervesce, a pungent gas will be given off and a bright yellow jelly will be formed gradually, without any sediment being present in it. If powdered limestone or cement rock is mixed with the cement the effervescence will be violent, strong fumes will be given off until the carbonate of lime has been driven off when it will form a bright yellow jelly. Powdered sand, quartz or silica mixed with cement will form a sediment at the bottom of the yellow jelly, when submitted to this test. It is hardly necessary to point out that cement which has any of the foregoing mentioned substances mixed with it, is an impure cement, and consequently as such must be rejected.

Tensile Strength.—Portland cement should bear a load of at least 350 lb. per sq. in. in 7 days, and 600 lb. in 28 days.

When mixed with three parts of standard sand by weight it should bear a load of at least 150 lb. after 7 days, and 200 lb. in 28 days.

Magnesia.—The percentage of magnesia in cement should not exceed 4 per cent.

Sulphuric Anhydride.—The percentage of sulphuric anhydride must not exceed 1·75 per cent.

Selection of Cement.—When the construction under consideration is not of a kind to justify the testing of different cements before making your choice, the question repeatedly arises as to whether, for example, natural or Portland cement is the more desirable for economy, or whether common lime and cement is more suitable for the purpose. These decisions more often than not depend almost entirely upon the conditions prevailing in the locality in which the material is to be used. Nevertheless one or two general rules or maxims may be formed relating to the classes of construction for which different kinds of cement and lime are adapted.

Portland Cement is obtained by finely pulverizing clinker produced by burning to semi-fusion an artificial mixture of finely ground calcaneous and argillaceous materials, consisting mainly and approximately of three parts of carbonate of lime to one part of silicaa, alumina and iron oxide.

The only sure discriminating test of Portland cement is by chemical analysis and its specific gravity. Its colour is a cold bluish grey, but it cannot be distinguished by this property, as both Puzzolan and natural cements have very similar colours.

Joseph Aspdin, a bricklayer of Leeds, discovered Portland cement and patented it in 1824. He called it by this name owing to its resemblance in colour to the famous building stone which is quarried at Portland. He originally prepared it by lightly calcining a mixture of lime and clay. He established a factory for its manufacture at Wakefield in 1825. It was used extensively as early as 1828 by Brunel in the construction of the Thames Tunnel. Portland cement ought to be used in concrete and mortar for structures which are to be exposed to severe and repeated stresses ; for concrete building construction ; for subaqueous work for thin walls subjected to water pressure ; for masonry destined to undergo wear or to be exposed to the elements ; and for other purposes where its cost will be less than that of natural cement or mortar.

Natural Cement is made by calcining natural rock at a heat below incipient fusion and then grinding the product to a powder. It contains a larger proportion of clay than hydraulic lime and is consequently more strongly hydraulic than it. Its composition is naturally extremely variable on account of the difference in the rock used for its manufacture. The best known natural cement is Roman cement. Natural cement may be substituted for Portland cement in concrete, if economy demands it, for dry, unexposed foundations where the compressive stress cannot exceed 6 tons per square foot, and where it will not bear any stress until three months' time from its being laid. It may be used for backing or filling in mass concrete or stone masonry where weight and mass are the essentials ; for sub-pavements of streets and also for sewer foundations. In mortar natural cement is used for ordinary brickwork which is not to be subjected to high water pressure or to come in contact with water until one month after it has been laid. Natural cement concrete or mortar must never be allowed to freeze ; must never be laid under water, in exposed conditions, in columns, beams, floors, or building walls, and must not be used in marine construction work.

Puzzolan or Slag Cement is the product resulting from mixing and grinding together in definite proportions slaked lime and granulated blast furnace slag or natural Puzzolan matter, such as Puzzolan, santorin earth, or trass, obtained from volcanic tufa. The ancient Roman cements belong to this class. Puzzolan or slag cement has a lilac colour ; no trace of grit can be found in it ; and it sets much more slowly than Portland cement. It should be used only in dry mixtures and then must be extremely well rammed. This species of cement never becomes extremely hard like Portland cement, but Puzzolan mortar and concrete are tougher than Portland cement, and are well adapted for use in sea water and in all cases where constantly exposed to moistures ; such as in foundations to buildings, sewers, drains, and all subterranean works. Puzzolan cement is entirely unsuitable for cases in which it would be subjected to wear, attrition, or blows. It should never be used in places where it may be exposed to dry air for long periods.

Hydraulic Lime has the property of setting under water, and on account of this property is extensively used in water work.

Common Lime is manufactured by a continuous process. It consists practically of calcium oxide. On being mixed with water it slakes and forms calcium hydrate ; and on a further quantity of water being added it increases to two or three times its original volume before any water was mixed with it, and is commonly known as putty or paste. It is entirely unsuitable for concrete as it will not set when in contact with water. It is incapable of supporting heavy loads, and is unable to offer any resistance to wear and tear, but is used extensively for mortar in buildings.

Testing the tensile strength of Cement.—These tests are made primarily to determine whether the ingredients of the cement and the process of its manufacture are such that a continued and uniform hardening may be expected in the work, and whether its strength in mortar or concrete is sufficient. Tensile tests must be combined with other tests, particularly that of soundness, in order to arrive at correct conclusions.

The periods universally selected for determining the tensile strength are 7 days and 28 days after moulding the briquettes. In each case the briquettes should be allowed to stand in the air for 24 hours and then should be immersed in water for the rest of the time before testing.

The results obtained much depend on the skill of the operator who makes the briquettes, and it should be distinctly understood that such work should be done by a skilled and experienced hand, and consequently should not be left to the care of an ordinary bricklayer's assistant, as is often the case.

The shape of the briquette has more effect on the result than one would first imagine. The original form of briquette used had a rectangular shape, which was a source of weakness. Thus briquettes have been modified in shape until that now in use was arrived at.

When seven days have elapsed from the moulding of a briquette made of Portland cement it should stand a tensile stress of about 400 lb. per sq. in., and after 28 days it should stand about 600 lb. per sq. in. In the case of natural cement the results are much less, *e.g.*, a briquette made under the conditions just described should stand after 7 days a tensile stress of 160 lb. per sq. in., and after 28 days 280 lb. per sq. in.

When making the briquettes care should be taken to ram the cement well to ensure the expulsion of all air, otherwise there will be air holes and the tensile stress will not be a fair one.

Aggregate.—Concrete may be defined as an artificial stone, made by mixing cement, or some similar material, which after mixing with water will set and adhere to inert material, and an aggregate composed of hard, inert particles of varying size, such as a combination of sand or broken stone screenings, with gravel, broken stone, cinders, broken brick, or other coarse material.

The author has dealt briefly with cement, and now proposes to do so with the question of aggregate before proceeding to discussion on concrete itself.

The rocks commonly employed for concrete are commercially classified as follows :—

(*a*) Traps, (*b*) Granites, (*c*) Limestones, (*d*) Conglomerates, (*e*) Sand stones.

Traps are dark green to black in colour, heavy, close textured and tough rocks of igneous origin.

Granites include the lighter coloured, less dense rocks, such as granite, syenite, diorite, gneiss, mica schist, and several other groups.

Limestones are not very suitable for concrete.

Conglomerates consist of a very coarse grained sandstone and make a very good aggregate.

Sandstones do not, as a rule, make a good aggregate.

CONCRETE.

The question whether concrete, which may be called a form of artificial masonry, is preferable to some other form of masonry is being repeatedly asked ; and may frequently resolve itself into a question of cost which is so often the deciding factor in a case where doubt is entertained as to which material to use. The cost, however, is dependent in its turn on the nature of the structure, the cost of labour, and the price of the materials employed in the work. Consequently before getting out an estimate of the cost of any piece of work to be done in concrete, the materials must be selected and the proportions of ingredients settled.

Portland cement concrete is extensively used in heavy foundation work, tunnels, subways and other subterranean structures. It is also extremely efficient for foundations for engines and machinery ; heavy walls, piers, abutments and floors on the ground level. When properly reinforced with steel it provides the most economical and effective fireproof material. Its use for walls of buildings is increasing daily, but on account of the indefinite time required for building and moving the shuttering, the cost may largely exceed the original estimate unless the builder has had experience of this sort of work.

Under favourable conditions a 6 inch wall of concrete will cost no more, and indeed sometimes less, than a 12 inch wall of brickwork, and will have the advantages of being stronger, more durable and fireproof.

Concrete is used and will be extensively used in the construction of tanks and vats for holding liquids that attack wood and iron. Their construction is simple, but the work must be carefully done to ensure success.

Other classes of work for which concrete is very suitable and in which it is extensively used are dams, retaining walls, bridges, abutments, sewers, water conduits, and reservoirs. Concrete can also be used for ornamental work in much the same way as plaster of Paris is used for that purpose.

Selection of Materials for the Manufacture of Concrete.—Concrete is ordinarily composed of cement, sand, gravel or crushed stone, or both, and water. The selection of these materials is largely dependent upon the local conditions and hence no hard and fast rule can be laid down in regard to it, but there are some general conditions which may serve as a guide to the inexperienced.

Cement.—It is wise to use Portland cement whenever possible for nearly all classes of work as it is more uniform and hence more reliable than Natural cement, whilst its strength exceeds that of any other cement.

For small work one or two tests for each load of cement should be made in the simple and rapid manner previously described, but for large work complete specifications should be prepared, and the cement should be tested to determine whether the requirements set out in the specification have been complied with.

Aggregate.—This term means the sand and broken stone or gravel. The sand should be clean. Some idea of its cleanliness may be obtained by placing it in the palm of one hand and rubbing it with the fingers of the other. If the sand is dirty it will badly discolour the palm of the hand. If, however, the use of dirty sand is unavoidable its effect upon the strength of the concrete must be investigated and allowed for. Coarse sand or a mixture of coarse and fine sand is preferable to the use of fine sand alone. The coarse material of the aggregate can be either crushed stone or clean gravel, or both. This is usually decided by the cost of the materials delivered at the work. If gravel is chosen greater uniformity is obtained by screening it over, say a $\frac{3}{8}$ in. mesh screen, and then remixing the sand that falls through the screen with the coarser gravel in definite proportion, than by taking the run of the bank.

If the gravel is dirty or clayey it should be washed with a hose, a little at a time.

Broken stone, if selected, need not be passed through a sieve, but may be used straight from the crusher, although it is preferable to screen out the dust and use the screenings as a portion of the sand. The maximum size is usually $2\frac{1}{2}$ inches.

Proportions.—When engaged upon large and important structures it pays from an economic standpoint to make very thorough studies of the materials and their relative proportions. Since the cement is always the most important and the most expensive ingredient of concrete, it is to that material that we first look. The reduction of the quantity of cement used may often be very appreciable in the case of large works by adjusting the proportions of the aggregate so as to use less cement and yet produce a concrete with the same density, strength, and impermeability as one with which this adjustment has not taken place. As an example of this economy, the ordinary mixture for a watertight concrete is about, 1 : 2½ : 4½ : that is to say, 1 barrel of cement, 2½ barrels of sand, and 4½ barrels of gravel or broken stone. By carefully grading the materials by mechanical analysis, a water tight concrete just as efficient, has been made with a mixture, of 1 : 3 : 7, saving by this method 0·36 of a barrel of cement per cubic yard of concrete, the value of which in a large piece of work amounts to a high figure. As a rough guide to the selection of materials and their proportions we may take four proportions which differ from each other simply in the relative quantity of cement contained in each mixture.

A Rich Mixture.—1 : 2 : 4, for reinforced machine-foundations subject to vibrations, for reinforced floors, beams and columns for heavy loading, tanks and other watertight work, gravel or broken stone.

A Medium Mixture.—1 : 2½ : 5, for ordinary machine-foundations, thin foundation walls, building walls, arches, ordinary floors, foot pavements and sewers.

An Ordinary Mixture.—1 : 3 : 6, for heavy walls, retaining walls, piers and abutments which are subjected to considerable forces.

A Lean Mixture.—1 : 4 : 8, for unimportant work in mass where the concrete is subjected to a plain compressive stress, as in large foundations that support a stationary load or, for the backing for stone masonry.

The foregoing proportions are based on a fair average, but if the aggregate is carefully graded and the proportions are re-adjusted, smaller proportions of cement may be used for each mixture, thereby considerably diminishing the relative cost of large work.

Contractors without experience of work in concrete have frequently lost heavily on a job tendered for in this material by assuming that the quantity of gravel plus the quantity of sand required will be equivalent to the volume of the finished concrete. This is entirely erroneous as the grains of sand fill, to a certain extent, the spaces between the larger pebbles, so that the volume of concrete is less than the volume of its ingredients. It is also important that one should bear in mind that if aggregate of uniform size is employed on the work it will cost from 5 to 10 per cent. more, on account of the additional amount of materials that will be required to fill up the space to make the required quantity of concrete. In measuring the gravel or stone before mixing there will be less solid material in a measure, and consequently more sand and cement will be necessary to fill in the spaces between the stones.

It is obvious that a volume of uniform stones contains less solid stone than an equal volume of graded stones. The spaces between the stones in the first case are nearly equal to the volume of the solid stones, and as the measure of the sand is one half that of the stone, and as the particles of cement fill in the voids between the particles of the sand, the cement and sand occupy a volume, only just exceeding that occupied by the stone. Hence instead of filling up a space of say 1 cubic yard with the mixture, only about nine tenths of the required volume is obtained, which will cause a serious loss to the contractors when doing work on a large scale unless allowed for.

Tools and Apparatus Necessary for the Work.—The number of tools will vary with the number of men employed on the work, which in turn will vary with the size of the work and with the expediency with which it is to be carried out.

The following schedule is provided for a gang of eight or ten men :—

Eight square pointed shovels.
Three iron wheel-barrows.
Two rammers.
One mixing platform, about 15 feet square and having a small parapet round the edge to prevent waste.
One measuring box or barrel for sand, and also a separate one for the measurement of gravel.
Timber for making the shuttering.

The most suitable timber is green spruce or fir lumber. If a smooth face on the work is required, the surface of the timber next to the concrete must be made smooth and dressed with oil. The shuttering must not be water tight, but must be just capable of allowing all surplus water to escape from the work without bringing any of the materials with it. The shuttering, which is usually laid horizontally, must be from 1 in. to 2 in. thick. The studs, or spikes, must not be more than 2 feet apart if the thickness of the sheeting is one inch, and when it is two inches thick must not be more than five feet apart.

When a thin wall of concrete is being made and it is required to strengthen it at the base, this is easily done by starting the shuttering about six or seven inches above the bottom of the excavation, thus allowing the concrete as it is put in the moulds to spread out at the bottom, forming a base as desired. By this simple, but entirely effective method, footings are provided for the wall. If there is earth or water pressure against the wall, the forms must be left up in their respective positions for at least three or four weeks, but if there is no such load imposed, then after the concrete has been in position for a period of twenty-four hours, or until it has set, the forms may be moved.

Mixing of Concrete.—To the ordinary onlooker the mixing of concrete is so absolutely simple that they would remark it is unnecessary for anyone to say anything about it, but this is not the case. It is of the greatest importance that the mixing of concrete should be properly carried out, as otherwise all its advantages over other forms of masonry will be nullified. The mixing of concrete is hard labour, and in consequence it takes a certain time to do. Therefore, it is necessary that the engineer should see that the concrete is properly mixed, as the contractor may lay it before it is properly mixed, and so save time and gain money. There is a book called "Scamping Tricks," which is full of interest to an engineer, as it consists of the confessions of two formerly large and well-known contractors. In it they expose to the engineer all the little tricks that they have at various times employed in order to gain time and money. These men devote a whole chapter to the subject of concrete, and in it are revealed several tricks for which the engineer must keep a sharp look out. The materials of which the concrete is to be made ought to be deposited as near the work as is possible. All damp must be prevented from getting to the cement, and this can best be accomplished by covering up the sacks or tubs of cement with corrugated iron sheeting, as one often sees done.

There are, at least, two distinct methods of mixing; (1) Mixing it by hand; (2) Mixing it by machinery. Here again cost comes into the question.

If the job is a small one, it is safe to say that the cheaper way will be to do the mixing by hand. Similarly, if the work to be carried out is extensive, then it will pay the contractor to do the mixing by machinery, thus saving a considerable amount of time and money which will more than remunerate him for the money and time spent on the machinery.

In all mixing great care must be taken with the following details:—

The exact measurement of the aggregate. Thorough mixture of the cement and sand. Thorough mixture of the mass. Careful depositing of the concrete. That the proper quantity of water is used. That the ramming or puddling of the concrete, done to ensure the absence of any air in the concrete, is properly and thoroughly done.

The cement should be measured by weight. The aggregate should be measured by the cubic foot.

The types of mixing machines are various, but they usually depend on one of the three principles :—

(1) Rotary mixing ; (2) Paddle mixing ; and (3) Gravity mixing.

Placing Concrete.—Concrete should be laid in layers about six inches thick. Each layer should be well rammed or puddled.

The usual method of transferring concrete from the mixing platform to the work is by means of a wheel-barrow, when the concrete has been mixed by hand. When mixed by machinery it is usually carried in cars running on a track, the cars being of the tipping type.

The Ramming of Concrete may be done by hand or machine, the latter usually being effected by a pneumatic rammer. This is much quicker than hand work and is more effective, as it is sure to do its work properly, whereas if the navvy gets a chance he will not do his work properly.

(*To be continued.*)

CONCRETE & REINFORCED CONCRETE.

(*Concluded.*)

By H. M. Wilson.

[*See Introductory Note at the beginning of the first part of this paper in our last issue.*]

Reinforced Concrete.

This is a form of construction that is engaging the attention of the best engineers. There is no doubt that many large structures in the future will be made of reinforced concrete, especially in the case of reconstruction work after the war.

Reinforced concrete has existed in practice and theory for more years than one would perhaps imagine. It is generally recognised that Mons. Monier was responsible for the first combination of steel and concrete, in order to produce a stronger material, as long ago as 1860. Metal had been used in conjunction with concrete previous to this, such as in the dome of St. Paul's Cathedral, and in some Roman work, but it is believed that these were instances of conjecture rather than calculation.

Portland Cement is the finest material for the preventing the corrosion of iron and steel, but only if applied in the proper manner. People realized this, but were under the impression that the unequal expansion of the two materials would cause a combination to be a failure through their not adhering to each other. This theory was exploded by the experiments of Hyatt, Bonniceau, and others which conclusively proved that for all practical purposes the expansion of steel and concrete are the same. The coefficients of expansion for these materials being concrete, 0·000,006, and steel, 0·000,0065. After this the use of reinforced concrete became more extensive, and it has been increasing ever since, gaining greater popularity for constructional work each year, on account of its excellent and peculiar properties. Reinforced concrete is fire proof, incorrodible, vermin proof, increases in strength with age, and is unaffected (owing to its monolithic form) by vibration, and sometimes even by earthquakes.

America is at present the leading nation in reinforced concrete work, whereas England ranks only fourth amongst the nations in this work. It is sincerely hoped that this may not be the case for long, for England with her splendid engineers should be able to make great strides in this comparatively new branch of constructional work.

The Moduli of Elasticity of Concrete and Steel.—The modulus of elasticity of concrete has not as yet been accurately determined, the results of experiments varying from 6,000,000 lb. per sq. in. to 500,000 lb. per sq. in. The modulus of elasticity of steel is far more constant, viz.: 30,000,000 lb. per sq. in. The ratio of the modulus of elasticity of steel to that of concrete is generally taken as 10, though some recommend the value 15.

Adhesion of Concrete to Steel.—This depends on two things, namely the area of the surface of contact and the nature of the concrete. For the best concrete the minimum adhesion is about 275 lb. per square inch. This is only theoretical however, and in order to prevent the steel slipping through the concrete, owing to the diminution of the cross sectional area of the steel when loaded, the adhesion is taken as 100 lb. per square inch. This uncertainty leads to the different forms of patent bars designed to avoid the necessity of having to rely on the surface friction by providing a mechanical bond between the steel and the concrete.

General Theory of Reinforced Beam Action.—It is generally assumed that the normal stress on a vertical section of a beam varies with the distance from the neutral axis, consequently the curve of the stress is a straight line.

The bending moment, and the resulting tensile and compressive forces have a maximum value (in the case of a beam freely supported at its ends and loaded with a uniformly distributed load) at the centre, and decreased to zero at the ends of the beam.

A beam reinforced horizontally alone fails through diagonal tension, for although the shearing stress may not in itself be sufficient to cause the failure of the beam, however small the amount of shearing force, it is accompanied by a considerable amount of diagonal tension.

In experimental work it will nearly always be found that a beam reinforced without provision being made for diagonal tension will break with 100 lb. per sq. in. of shearing stress on the section, owing to the diagonal tension that results from it.

In theory the stirrups should be perpendicular to the lines of stress, but this is impracticable owing to the fact that the inclination of these lines is different at different points in the beam. The angle of 45 degrees occurs only at the neutral axis, and so there is really no reason why the stirrups should not be vertical, which is practically always the case, as stirrups set vertically are far less liable to get out of position when the concrete is put in place than they are if set an angle. The greatest diagonal tensile stress occurs at the extremities of the beam and it is, therefore, customary to bend up some of the tension bars towards the end so as to resist this force.

It is quite easy to put vertical stirrups in place, and they form a connection between the tension and the compression areas.

The adhesion of the bars to the concrete transmits the stress from the bars to the concrete, consequently this must always be checked as much as the tension in the steel.

Horizontal bars placed near the bottom of the beam provide sufficient reinforcement for the central part of the beam, but additional reinforcement must be used at the extremities to meet the diagonal tension, as has already been mentioned.

Action of a Reinforced Concrete Beam under Loading.—(1). The beam acts as a true combination of steel and concrete until a stress of about 3,000 lb. per sq. in. occurs in the steel.

(2). The neutral axis then rises and the concrete loses some of its tensile value, and the tensile stresses formerly taken by the concrete are taken by the steel.

(3). The position of the neutral axis remains fixed as the concrete has lost its remaining resistance to tension. Thus it is seen that the resistance of the concrete affects the deformation and deflection of the beam when the loads are small, but with greater loads the steel alone does takes the tension, the resistance of concrete to tension usually not being taken into account.

Centering.—It is absolutely essential that the concrete should not be disturbed after it has been put in place, and on that account the centering must be of such a nature and design as to prevent this taking place and so that it can be easily eased and removed without producing a jarring effect on the recently completed work.

As in cast iron construction, it is desirable that there should not be any sharp corners, so in concrete work all sharp corners must, wherever possible be avoided, and round corners be constructed.

The timbering, forms or shuttering used in concrete work can be lime washed or greased so as to give a rendering to the work and at the same time make their removal less difficult. A camber of at least $\frac{1}{4}$ in. in a foot should be given to all beams and slabs of reinforced concrete. The joints should be such that little leakage can occur. The forms should be arranged in such a way that the sides of columns can be moved first, then the sides of the beams and the centering, and lastly the supports below the beams themselves.

The sides of the columns can generally be removed about a week after the laying of the concrete. 14 days from the time of placement is usually allowed for the removal of centerings. The beam supports are allowed to remain in position longer so that the concrete may have a better opportunity of setting hard before the beam has to support the full dead load. The beam supports may usually be removed after three weeks from the time the concrete was put in place, but in cases of large spans this time should be increased.

The removal of all kinds of centering and forms requires a considerable amount of experience, and must only be done under the directions and supervision of the engineer in charge, as it involves great responsibility.

Water.—The amount of water required for mixing concrete depends upon the weather at the time of mixing as well as upon the nature of the aggregate and the sand. The concrete when mixed should be sufficiently plastic to remain at an angle of about thirty degrees in a barrow and not wet enough to drip when placed upon the centering. After the concrete has been rammed the water should just ooze to the surface.

Steelwork.—The steel should stand a stress of 34,000 lb. per sq. in. before any appreciable set is apparent. It should stand bending, when cold, to an angle of 180° round a bar of the same diameter without any fracture. No concrete work should ever be carried out when the temperature is that of freezing, or indeed if it falls below 39° F., as at that temperature water is at its maximum density. If concrete has taken its initial set before frost comes on then it is quite all right, but the forms and centering must be left up for an extra period of time corresponding with the time the frost lasted.

Should a frost occur when the work is newly laid, it should be covered with sacking.

Placing of Reinforcements.— The steel must be in such positions that it acts in the best possible manner and as shown on the working drawings, and it is the duty of the engineer in charge to see that this is done. It is also of the greatest importance that they are not moved from their positions by the laying of the concrete. Concrete should be kept slightly wet for at least seven days after it has been laid. Careful examination must be made before the concrete is laid to ascertain whether there is any dirt in the centerings, and if there is it must be all removed before any concrete is introduced. All the centerings and forms should be wet at the time of laying concrete, so that the timber may not absorb any of the moisture from the concrete. Whenever possible the concrete should be placed in position from as small a height as possible, owing to the tendency of the cement to separate from the other ingredients when dropped from a height. All the concrete must be well rammed, especially round the steel bars.

The ends of bars, projecting from any recently completed work must not be knocked or jarred, as such an action would damage the final set of the concrete and thus reduce its strength.

Columns.—In square columns three of the four sides are shuttered before the work is commenced. The steel bars are then put in place and the concrete is introduced from the open side, the fourth shutter being built up as the work proceeds.

Beams.—Sometimes it is found difficult to make the concrete pass between the bars of a beam, and in such cases the concrete may be made more liquid than usual.

Slabs.—When the centering has been erected, the bars should be placed in the positions allotted to them on the working drawings, being kept apart for the time being by the use of templates. The crossbars are wired to the main bars at frequent intervals and serve to keep the latter in position.

Corrosion of Steel in Reinforced Concrete.—Much is said now-a-days on the question of the corrosion of the steel bars in reinforced concrete, a considerable amount of practical evidence, however, enables all engineers experienced in reinforced concrete to state most emphatically that under no conditions is the steel adversely affected by the concrete. Chemical action takes place between the cement and the steel, calcium ferride is formed, and this prevents corrosion taking place.

In order to demonstrate, in a purely non-technical manner, the great difference there is between the strength of ordinary and reinforced concrete, the Author made two beams, one of reinforced concrete and the other of plain concrete. They were both of the same dimensions, each being two feet long, one inch deep and 1½ inches wide. The concrete in each consisted of :—Three parts of sharp river sand to one of slow setting Portland cement. The reinforced beam had bars of an alloy, which consisted mostly of zinc, no steel bars small enough being obtainable. The reinforcing was placed ⅛ inch from the bottom of the beam. The stirrups were made of copper bell wire, six being placed at each end of the beam.

The beams stood the following loads : Plain concrete beam—120 lb. at the centre. The reinforced beam—470 lb. at the centre.

In conclusion the Author would like to urge upon his fellow students the advisability of reading up this subject which is not only interesting to all engineers, but which will undoubtedly be the great structural material of the near future.

VISITS.

There has been considerable difficulty this year in arranging for the usual visits during the summer. Of eleven firms who were requested to allow such visits only two were able to grant the necessary permission.

The first visit took place on the 11th July, 1916, and was to a portion of the works of Messrs. Johnson & Phillips, at Charlton, S.E., including a large plant for the manufacture of telephone cables capable of dealing with cables up to 1,000 pairs of small wires for local lines, and also " trunk " cables consisting of fewer but heavier wires.

One shop contained a number of multiple-headed machines for covering the single wires with one or two layers of paper put on longitudinally or spirally, and forming a more or less loose tube of paper ; also a number of special high speed twinning machines, which are used to twist two of the covered conductors together, forming the " twin," which is wound on to a larger bobbin. These bobbins are taken to the " laying-up " machines in another shop.

Several of the " laying up " machines are arranged for laying-up 7-pair telephones, cables, of which large quantities are made.

Other larger machines consisting of three or four sections, each carrying different numbers of bobbins, are designed to " lay-up " the twinned conductors into cables, each layer of conductors being stranded in opposite directions. These machines will deal with cables up to 150 pairs. If the cable has to be made up with a larger number of pairs, it then goes to a still larger machine having four or five sections, the largest of which carries 70 standard bobbins, or, if necessary, 100 or more narrower bobbins.

The cable can be built up in this machine with several more layers of conductors put on in opposite directions, until it reaches a total of 800 to 1,000 pairs, according to requirements. The cable so made is coiled on to steel drums, which are then placed in large steam-heated hermetically sealed chambers to dry the paper covering, the moisture being carried off by means of an air pump, which causes a more or less perfect vacuum in the chamber.

When the cable is thoroughly dried it is taken to the lead covering press, and coated with lead. These presses consist of a lead container having a point of core and die through which the cable to be covered passes. Two hydraulic rams are arranged to work into the lead container and operated on the lead. Above the container is the lead melting pot, the molten lead being run from the pot into the container, where it is allowed a few minutes to " set," and then the hydraulic pressure is applied. The point or core through which the cable passes is cone-shaped, so that when the pressure is applied the lead moves forward off the core and through the die, this being the only exit, and the point of the core being close to the die, a tube of lead is formed of such size as to cover the cable, take a grip of it, and pull it through the press as the pipe is formed. The cable so covered is coiled on to drums and tested under water, with the ends of the pipe and cable projecting, to see that the pipe is quite sound and watertight. These lead covering presses can deal with cables of any practicable length, without any joint in the lead pipe, because when a charge has as far as practicable been extruded, the hydraulic ram is withdrawn, and a further charge of molten lead is run into the container, and automatically burns itself on to the block of lead which is left in the chamber and around the cable.

In the same department there were a number of stranding machines of various sizes for dealing with copper strands composed of different sizes and numbers of wires as used for cables for power transmission and lighting, also a number of paper insulating machines for covering these strands with varying numbers of layers of paper according to the thickness of insulation required. These machines each had four or five heads, each head having three arms, and each arm adapted to carry three discs of paper, enabling the machines to put on 36 to 45 layers of paper at one operation. The heads of these machines have hollow mandrils through which the cable passes, while the head revolves, laying the strips of paper on the cable spirally. From these machines the cable is coiled into steam-heated hermetically sealed pans, all moisture being evaporated and drawn off by means of an air pump. A resinous compound is admitted into the pan while it is still under vacuum, and the dried paper readily takes up the compound, and in a short time becomes thoroughly saturated. When this condition is reached the vacuum is broken, the pan opened, and the cable is passed through the lead-covering press as before described in connection with the telephone cables.

After lead covering, the power and lighting cables are usually armoured with steel wires or steel tapes, and protected with preservative tapes or jute yarns and compounds. The wire armouring machine is practically the same as a large stranding machine, arranged to carry a large number of bobbins, it sometimes being necessary to use as many as 100 or more wires.

The steel taping machine has a very massive head provided with two worm-adjusted quadrants, each of which carries a coil of steel tape. The head has a hollow mandril, through which the cable passes, and the head revolving lays the tapes on the cable helically. Each tape is laid on in an " open " helix, the tapes being adjusted so that the outer one covers the space between the coils of the inner tape, so as to provide a perfect shield. Over the steel tapes it is usual to put one or two tapes or layers of jute and compound, and this is done at the same tiem as the armouring.

In the rubber cable department were seen wires and cables of various sizes being covered with pure and compounded rubbers, afterwards vulcanised and protected by tapes, braiding, etc. Especially interesting were the longitudinal rubber covering machines, which are arranged to cover 12 conductors simultaneously with two, three or four layers of rubber. In these machines the wires are made to pass side by side through grooved rollers, while strips of rubber are fed in with the wires, one above and one below, the rollers crushing the rubber strip together between the wires, and practically forming a band of twelve covered wires with a fine fin of rubber between them.

The crushing of the rubber has the effect of uniting the two strips of rubber at the side of each wire, and the fin is so thin that the band easily splits up, leaving twelve separate covered wires which are coiled on to separate drums.

These rubber-covered conductors are then wound on to steel cylinders, and placed in steam-heated pans, in which they are submitted to a certain temperature for a certain period, according to the size of the wire or cable, and to the quality of the rubber being dealt with. After this operation the cable is protected with tapes or braiding and preservative compound, according to specification.

For making the smaller strands Messrs. Johnson & Phillips, Ltd., have installed many of their latest high-speed stranding machines, which run at speeds of 1,250 to 1,000 revolutions per minute. These are comparatively long machines, with bobbin carriages arranged in a long cage; tandem to one another, and supported in ball bearings, in such a manner so that they remain stationary while the cage revolves around them. The cages are splendidly balanced, and they are supported at intervals in their length on special rollers, which ensure very quiet running.

In addition to the stranding and covering machines there were also various machines for cutting the rolls of rubber and cloth into strips to suit the various sizes of conductors.

The majority of the rubber-covered cables when completed are tested under water, and the visitors saw several large testing tanks and special testing rooms engaged upon this work.

Practically all the machines used by Messrs. Johnson & Phillips, Ltd., in their cable-making department are of their own manufacture, this work being a speciality of theirs.

Owing to the short time at the disposal of the members we were unable to go through various other shops engaged in the manufacture of transformers, switchboards and switch gear, instruments, arc lamps, etc., but we spent a short time in the general engineering shop which is usually engaged in the manufacture of all kinds of cable-making machinery and of cable picking-up and paying-out gears and equipments for submarine cable steamers, but which this time was engaged on various munitions work.

At the conclusion of the visit the members were pleased to find that Messrs. Johnson & Phillips had thoughtfully provided tea and light refreshments. The President proposed a vote of thanks to the firm for the visit, which was carried by acclamation.

SECOND VISIT.

On 7th September, a visit was paid to the Nine Elms Works of Messrs. Dorman & Long. This firm is busily engaged on war work, and it was gratifying to see what a good stock of steel they had even at these works, which are undergoing certain improvements. The steel is not rolled at Nine Elms, but it is there that part of the firm's constructional work is done, consequently the processes we saw included marking out, cutting to length, punching, shearing, drilling, straightening, notching, trueing of ends, riveting (hydraulic, pneumatic and hand), smith's work, hydraulic forging, etc.

The machine that attracted most attention was a large friction "saw" for cross-cutting steel joists, channels, angles, etc. The "saw" is a mild steel disc $\frac{1}{2}$ in. thick and 4ft. in diameter. It has no teeth in the ordinary sense of the word, but the edge is notched with a slightly forked cold chisel, the notches being $\frac{3}{8}$in. apart. The effect is to make the edge rough and a little wider than the rest of the disc, thus affording clearance. The disc is coupled to a 45 H.P. electric motor, which drives the disc at 2,000 r.p.m. The peripheral speed of the disc is thus no less than five miles per minute! A small jet of water plays on the disc. We saw a 6in. × 3in. rolled steel joist cut across by this machine in 9 seconds, the ends being perfectly true and without the slightest distortion, which commonly occurs with shearing machines. The feeding of the machine is done by hand, as the man is able to adjust the feed to the speed of cutting or the quality of the material cut, *e.g.*, when going through a web the speed is faster than when cutting through the flanges. The "cutting" is really a melting. The friction of the edge of the disc is such that the steel of the joist is melted, and there is a fine display of fireworks due to the number of small globules of molten steel which are thrown off.

At the end of the inspection the visitors were provided by Messrs. Dorman & Long with a welcome surprise in the form of a quite dainty tea.

2nd October, 1916.

MR. PERCY GRIFFITH, M.I.C.E., PRESIDENT,

IN THE CHAIR.

THE DESIGN OF CONTINUOUS BEAMS.

By EWART S. ANDREWS, B.Sc. (Engineering), Lond.

INTRODUCTORY.—By a continuous beam we shall mean in this paper one that rests upon more than two supports ; a beam which rests upon two supports and is continuous over one or both (*i.e.*, overhangs one or both ends) will not be regarded as a continuous beam, because the stresses in it can be deduced by the application of the laws of simple statics, whereas when there are more than two supports we have to consider also the deflected form of the beam. For this reason continuous beams belong to the type of structures which are commonly referred to as "statically indeterminate." The real difficulty in the calculation of the stresses in continuous beams may be regarded as involved in the determination of how much the reaction on each support will be ; if we had any simple direct method of calculating the reactions upon the supports of a continuous beam, as we have in the case of a beam resting upon two supports only, the bending moments and resulting stresses could be determined at once.

When we speak of a structure as being statically indeterminate we mean that the application of the ordinary rules of statics (such as the rules that the sum of the vertical reactions must be equal to the total vertical load, and that the moment of the reactions about any point must be equal to the moments of the loads about that point) is not sufficient to determine the reactions ; in mathematical language we should say that "We have more unknowns than equations." In a statically indeterminate structure we have still to satisfy the requirements of the laws of statics, and we have, in addition, to consider the laws of elasticity which determine the manner in which the structure will be strained, *i.e.*, distorted.

Alleged Disadvantages of Continuous Beams.—Whilst most writers upon the subject admit the advantage of continuous beams from the standpoint of economy of material, particularly in large spans (and this, after all, is a most important advantage), they usually refer to their disadvantages under two heads : (1) complexity of calculations, (2) uncertainty and possible danger due to unequal settlement of the supports. These alleged disadvantages have apparently, in the minds of practical engineers, outweighed the advantages, because in the past continuous beams, in this country especially, have been but little employed. In many cases beams, apparently continuous, have been purposely designed weak at the supports to preclude their continuous action.

The first disadvantage can be met by systematic tabulation and diagrams, and becomes of less importance as our knowledge increases, but the second disadvantage appears to be the one which presents most difficulty in the minds of practical engineers. In answer thereto the writer would urge that in the case of ductile materials, such as mild steel, at least, it will not greatly matter if the safe stresses or even the yield-point stresses are exceeded, because the material is plastic beyond the yield-point, and the beam will deform slightly until the beam obtains a fresh safe bearing.

To make this point clear consider the case of a continuous beam of two spans in which the central support sinks for some reason or other, as shown in exaggerated form in Fig. 1. The explanation commonly given is that if we have two separate beams as in (*a*),

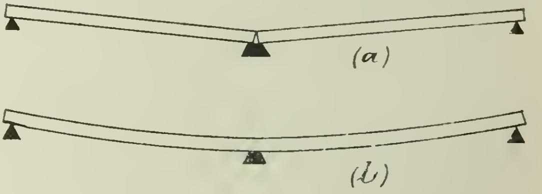


FIG. 1.

the two beams will become slightly tilted, but the stresses will not become unsafe ; whereas if the beam is continuous as in (*b*) the effective span becomes doubled, and the " ultimate strength of the material may be exceeded." This, however, is not the case because the beam will bend as soon as the yield-point in the material is exceeded, and will then get a bearing upon the centre support ; it will then remain permanently slightly bent, and the stresses will adjust themselves to practically their previous values because of the principle of least work, which states that the stresses in a loaded structure will adjust themselves so that the strain energy or work of deformation is a minimum.

This, in the case of a ductile material, appears to the writer to dispose of most of the second disadvantage, especially as with adequate design of the supports we ought not to expect any great difference in the settlement of the supports.

EFFECT OF CONTINUITY.—If a beam is continuous over more than two supports, such as A, D, E, Fig. 2, the deflected form of the beam has to take some shape such as shown, the curvature changing in direction at points such as *a*, *b*, *c*, *d*, which are called *points of contraflexure*, the bending moment at these points being zero. This change of curvature means that a negative bending moment occurs at the supports, the tension and compression sides of the beams then changing places; we shall in future refer to the negative bending moment as the " support B.M.," and the bending moment at any point, which would have arisen if each span had been separate and simply supported, as the " free B.M."

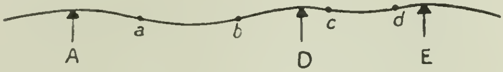


FIG. 2.

A change in the reactions, causing an alteration in the base-line, but not in the shape of the shear diagrams, also results. This alteration in the reactions is of great importance in practical design, but is sometimes overlooked by designers; we shall refer to it again in detail later.

THE THEOREM OF THREE MOMENTS.—All problems upon continuous beams can be solved by means of this theorem, credited to Clapezron, which, in its simplest form, gives the relation between any three consecutive support B.M.'s and the loading for a continuous beam of any number of spans at the same level.

Let A D and D E, Fig. 3, be any two consecutive spans of length l_1 and l_2 of a continuous beam of any number of spans, and let A *e* D, D *f* E be the free B.M. diagrams for the loading on these spans. Let verticals be drawn through the centroids of these free B.M. diagrams, and let them be at distances y_1 y_2 respectively from A and E, the areas of the diagrams being respectively

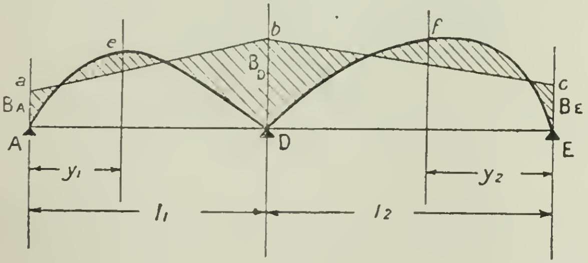


FIG. 3.

A_1 and A_2. Then, if B_A B_D and B_E are the support moments at A, D and E, the theorem states* that—

$$B_A l_1 + 2B_D (l_1 + l_2) + B_E l_2 = 6\left(\frac{A_1 y_1}{l_1} + \frac{A_2 y_2}{l_2}\right)$$

In the case of uniformly distributed loads of intensity w_1 and w_2 respectively, this becomes—

$$B_A l_1 + 2 B_D (l_1 + l_2) + B_E l_2 = \tfrac{1}{4} (w_1 l_1^3 + w_2 l_2^3)$$

Reactions and Shear Diagrams.—It is a law of structural mechanics that the shear at any point of a beam is given by the slope of the B.M. diagram at that point; the effect of making a beam continuous is to give a different base line to the B.M. diagram, so that in general the slope of the B.M. diagram at every point of the same span becomes changed by an equal amount, which will be $\frac{\pm (B_A - B_D)}{l}$ for the span A D. We therefore obtain the following method of dealing with the end shears and reactions in continuous beams, and it will be found much simpler to apply in practice than any other method which has been given.

Consider any support, say D_1 and let r_1 be the reaction at D due to the span l_1, if the separate spans were simply supported, R_1 being the corresponding quantity for the continuous beam.

$$\text{Then change in slope of B.M. curve} = \frac{B_D - B_A}{l_1}$$

$$\therefore R_1 = r_1 + \frac{B_D - B_A}{l_1}$$

Similarly, if r_2, R_2 are corresponding quantities for the span l_2—

$$R_2 = r_2 + \frac{B_D - B_E}{l_2}$$

Then R_1, R_2 give the ordinates of the shear diagrams on the left and right of D, and the total reaction at D is given by—

$$R_D = R_1 + R_2$$

Numerical Example.—A continuous girder, A D E F (Fig. 4), consists of three spans, 20, 10 and 15ft. long, and the first span carries 20 tons, the second 15 tons, and the third 10 tons, uniformly distributed. Draw the B.M. and shear diagrams.

First draw the B.M. diagrams as if the separate spans were freely supported.

---

* The theorem is proved in the author's text-books on *Theory and Design of Structures*, and *Strength of Materials* (Chapman & Hall, Ltd.)

Now take the first two spans, then by the theorem of three moments—

$$M_A \times 20 + 2\,M_B \times 30 + M_C \times 10 = \frac{1}{4}\left\{\frac{20}{20} . 20^3 + \frac{15}{10} . 10^3\right\}$$

But the end A is freely supported. $\therefore M_A = 0$

$$\therefore \text{ we get } 60\,M_B + 10\,M_C = \frac{10^3}{4}\left(8 + \frac{15}{10}\right)$$

$$\text{or } 6\,M_B + M_C = 237 \cdot 5 \text{ ....(1)}$$

Now consider the next two spans. Then we have

$$M_B \times 10 + 2\,M_C \times 25 + M_D \times 15 = \frac{1}{4}\left\{\frac{15}{10} . 10^3 + \frac{10}{15} . 15^3\right\}$$

The end D being freely supported, we have—

$$10\,M_B + 50\,M_C = \frac{5^3}{4}\left\{12 + 18\right\}$$

$$\text{or } M_B + 5\,M_C = 93 \cdot 75 \text{ ton-ft. .... (2)}$$

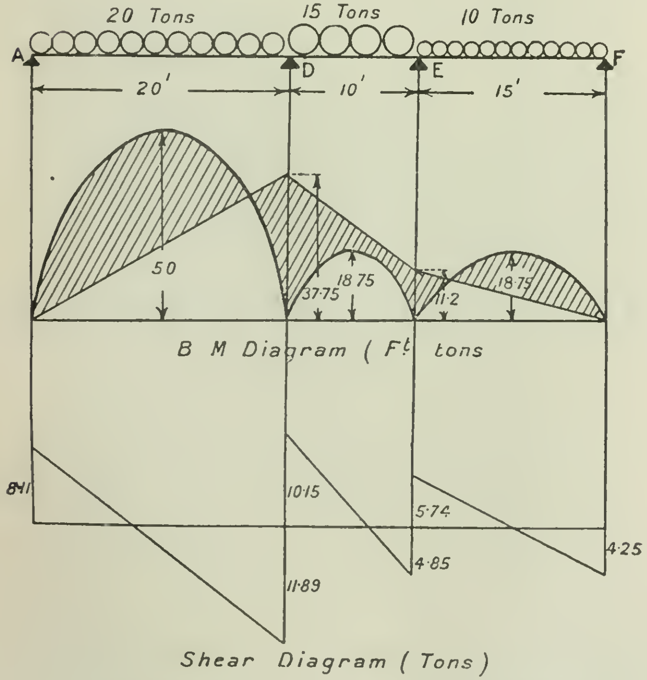


FIG. 4.—CONTINUOUS BEAM OF THREE SPANS.

Solving the two simultaneous equations (1) and (2) we get

$$M_B = 37{\cdot}75 \text{ ton-ft.}$$

$$M_C = 11{\cdot}20 \text{ ton-ft.}$$

$\therefore$ Putting up these values we get the B.M. diagram as shown in the figure.

To get the shear diagram we first calculate the reactions as follow—

$$R_A = \frac{w_1 l_1}{2} + \frac{M_A - M_B}{l_1} = \frac{20}{2} - \frac{37{\cdot}75}{20} \qquad = 8{\cdot}11 \text{ tons}$$

$$R_B = \frac{20}{2} + \frac{37{\cdot}75}{20} + \frac{15}{2} + \frac{26{\cdot}55}{10} = 11{\cdot}89 + 10.15 \quad = 22{\cdot}04 \text{ tons}$$

$$R_C = \frac{15}{2} - \frac{26{\cdot}55}{10} + \frac{10}{2} + \frac{11{\cdot}20}{15} = 4{\cdot}85 + 5{\cdot}74 \quad = 10{\cdot}59 \text{ tons}$$

$$R_D = \frac{10}{2} - \frac{11{\cdot}20}{15} \qquad = 4{\cdot}26 \text{ tons}$$

$$\text{Total} \ \ldots \qquad \underline{\overline{45{\cdot}00 \text{ tons}}}$$

The shear diagram then comes as shown in the figure. If there are more than three spans, consecutive spans are taken two together, and a series of equations is obtained by the theorem of three moments, from which the various support moments may be obtained. We give later a numerical example involving point loading.

TREATMENT FOR FIXED ENDS.—If one or both ends of a continuous beam are fixed, or "encastré," as it is sometimes called, we imagine to exist, beyond the end fixed-span, another span which is its mirror reflection, and then apply the theorem of three moments. If F (Fig. 5) is the fixed end support, and E the support next to the end, we shall then get the formula—

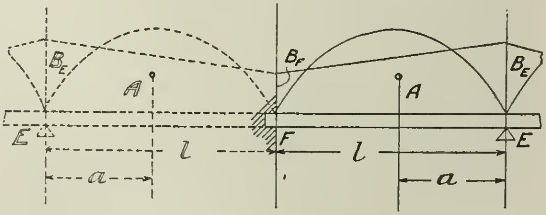


FIG. 5.

$$B_E l + 2\,B_F \,.\, 2\,l + B_E \,.\, l = 6\left\{\frac{Ay}{l} + \frac{Ay}{l}\right\}$$

$$i.e., \quad 2\,B_F + B_E = \frac{6\,Ay}{l^2}$$

for uniform loading— $A = \dfrac{wl^3}{12} \quad . \quad y = \dfrac{l}{2}$

.˙. our equation becomes—

$$2B_F + B_E = \frac{wl^2}{4}$$

Equal Spans with Constant Uniform Load.—In practice the spans (l) are often equal, and the uniform load (w) per unit length constant, the extreme ends being freely supported. The following tubular values can then be used :—

REACTIONS FOR CONTINUOUS BEAMS OVER EQUAL SPANS·

(*Coefficients of w l.*)

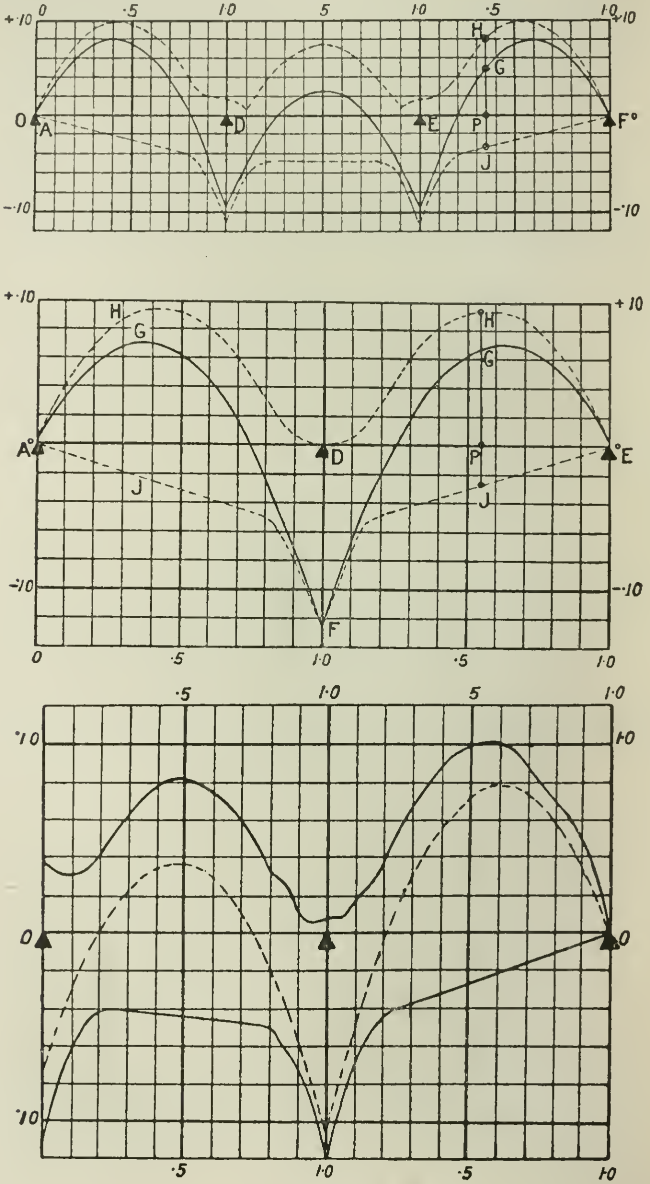
Number of spans.	Number of each support.									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
2	$\frac{3}{8}$	$\frac{10}{8}$	$\frac{3}{8}$							
3	$\frac{4}{10}$	$\frac{11}{10}$	$\frac{11}{10}$	$\frac{4}{10}$						
4	$\frac{11}{28}$	$\frac{32}{28}$	$\frac{26}{28}$	$\frac{32}{28}$	$\frac{11}{28}$					
5	$\frac{15}{38}$	$\frac{43}{38}$	$\frac{37}{38}$	$\frac{37}{38}$	$\frac{43}{38}$	$\frac{15}{38}$				
6	$\frac{41}{104}$	$\frac{118}{104}$	$\frac{100}{104}$	$\frac{106}{104}$	$\frac{100}{104}$	$\frac{118}{104}$	$\frac{41}{104}$			
7	$\frac{56}{142}$	$\frac{161}{142}$	$\frac{137}{142}$	$\frac{143}{142}$	$\frac{143}{142}$	$\frac{137}{142}$	$\frac{161}{142}$	$\frac{56}{142}$		
8	$\frac{153}{388}$	$\frac{440}{388}$	$\frac{374}{318}$	$\frac{392}{388}$	$\frac{366}{388}$	$\frac{392}{388}$	$\frac{374}{388}$	$\frac{440}{388}$	$\frac{153}{388}$	
9	$\frac{209}{530}$	$\frac{601}{530}$	$\frac{511}{530}$	$\frac{535}{530}$	$\frac{529}{530}$	$\frac{529}{530}$	$\frac{535}{530}$	$\frac{511}{530}$	$\frac{601}{530}$	$\frac{206}{530}$

BENDING MOMENTS FOR CONTINUOUS BEAMS OVER EQUAL SPANS.

(*Coefficients of* wl^2.)

Number of spans.	Number of each support.									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
2	0	$\frac{1}{8}$	0							
3	0	$\frac{1}{10}$	$\frac{1}{10}$	0						
4	0	$\frac{3}{28}$	$\frac{2}{28}$	$\frac{3}{23}$	0					
5	0	$\frac{4}{38}$	$\frac{3}{33}$	$\frac{3}{38}$	$\frac{4}{33}$	0				
6	0	$\frac{11}{104}$	$\frac{8}{104}$	$\frac{9}{104}$	$\frac{8}{104}$	$\frac{11}{104}$	0			
7	0	$\frac{15}{142}$	$\frac{11}{142}$	$\frac{12}{142}$	$\frac{12}{142}$	$\frac{11}{142}$	$\frac{15}{142}$	0		
8	0	$\frac{41}{388}$	$\frac{30}{388}$	$\frac{33}{388}$	$\frac{32}{388}$	$\frac{32}{388}$	$\frac{30}{388}$	$\frac{41}{388}$	0	
9	0	$\frac{56}{530}$	$\frac{41}{530}$	$\frac{45}{530}$	$\frac{44}{530}$	$\frac{44}{530}$	$\frac{45}{530}$	$\frac{41}{530}$	$\frac{56}{530}$	0

Diagrams for Uniform Live and Dead Loads.—The following diagrams, Figs. 6 to 8, sometimes called Winkler's Diagrams after their originator, give the maximum positive and negative bending moments at any point of a continuous beam of two, three or four



FIGS. 6-8.

equal spans, due to a dead load and a uniformly distributed live or rolling load. The curves give the actual bending moments and do not allow for any impact allowance.

A G F and E G F are curves for dead load ; A H D, E H D are maximum positive B.M.'s for live loads and A J F, E J F are curves of maximum negative B.M.'s for live loads. Suppose that each space is l, and that the dead load is w_d per unit length, and the live load is w_l per unit length. Then at any point P—

$$\text{Maximum positive B.M.} = (w_d\ \text{P G} + w_l \,.\, \text{P H})\, l^2$$

$$\text{Maximum negative B.M.} = (w_l\ \text{P J} - w_d \,.\, \text{P G})\, l^2$$

In the case of four spans, to save space we show the curve for the right half only ; the curves for the other half are the same reversed.

Messrs. Turneaure & Maurer* give the following tabulated results for maximum moments in continuous beams with equal spans :—

No. of spans.	Intermediate spans and supports.				End spans and second support.			
	At centre (+)		At support (–).		At centre (+).		At support (–).	
	Dead. (× w_dl^2)	Live. (× w_ll^2)	Dead. (× w_dl^2)	Live. (× w_ll^2)	Dead. (× w_dl^2)	Live. × (w_ll^2)	Dead. (× w_dl^2)	Live. (× w_ll^2)
2	—	—	—	—	·070	·095	·125	·125
3	·025	·075	—	—	·080	·100	·100	·117
4	·036	·081	·071	·107	·071	·098	·107	·120
5	·046	·086	·079	·111	·072	·099	·105	·120
6	·043	·084	·086	·116	·072	·099	·106	·120
7	·044	·084	·085	·114	·072	·099	·106	·120

The following approximate values of bending moments give results which are sufficiently accurate for most purposes in design :

Near middle of end span.	At last interior support.	Near middle of interior spans.	At interior supports excepting the last.
$+\left(\frac{w_l}{10}+\frac{w_d}{12}\right)l^2$	$-\left(\frac{w_l}{9}+\frac{w_d}{10}\right)l^2$	$+\left(\frac{w_l}{12}+\frac{w_d}{24}\right)l^2$	$-\left(\frac{w_l}{9}+\frac{w_d}{12}\right)l^2$

---

* *Principles of Reinforced Concrete Construction.* (Chapman & Hall, Ltd.)

ISOLATED LOADS ON CONTINUOUS BEAM OF TWO SPANS.

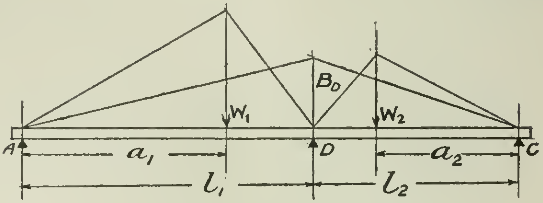


FIG. 9.

It frequently happens in practical design that we have isolated loads as well as uniformly distributed loads to deal with. In this case it is a good plan to compute separately the bending moments at the supports for the isolated and uniform loads, and then deduce the reactions and add them together. The bending at any point can then be found without difficulty.

In the case of two spans we have for isolated loads, Fig. 9—

$$A_1 = \frac{W_1\ a_1\ (l_1 - a_1)}{l_1} \cdot \frac{l_1}{2} = \frac{W_1\ a_1\ (l_1 - a_1)}{2}$$

$$y_1 = \frac{l_1}{2} + \frac{1}{3} \cdot \left(a_1 - \frac{l_1}{2}\right) = \frac{(l_1 + a_1)}{3}$$

Similarly—

$$A_2 = \frac{W_2\ a_2\ (l_2 - a_2)}{2}$$

$$y_2 = \frac{(l_2 + a_2)}{3}$$

As the ends A and C are both free, B_A and $B_C = 0$.

$$\therefore \text{ we have } 2\ B_D\ (l_1 + l_2) = 6\left\{\frac{W_1\ a_1\ (l_1 - a_1)}{2\ .\ l_1} \cdot \frac{(l_1 + a_1)}{3} + \frac{W_2\ a_2\ (l_2 - a_2)\ (l_2 + a_2)}{2\, l_2\ 3}\right\}$$

i.e., $$2\ B_D(l_1 + l_2) = \frac{W_1\ a_1}{l_1}\ (l_1^2 - a_1^2) + \frac{W_2\ a_2}{l_2}\ (l_2^2 - a_2^2)$$

i.e., $$B_D = \frac{1}{2\ (l_1 + l_2)} \left\{\frac{W_1\ a_1}{l_1}\ (l_1^2 - a_1^2) + \frac{W_2\ a_2}{l_2}(l_2^2 - a_2^2)\right\}$$

Special Case:—When $l_1 = l_2$; $a_1 = a_2$; $W_1 = W_2$.

In this case the above equation reduces to—

$$B_a = \frac{W\ a}{2\ l^2}\ (l^2 - a^2)$$

or, if $a = \alpha l$—

$$B_D = \frac{W \alpha l}{2} (1 - \alpha^2)$$

If the spans are equal, but the loads are not equal and symmetrically placed, we can consider each load separately, and use the following diagram (Fig. 10), which is a kind of influence-line for the reactions moment, reversing A and E for the second span.

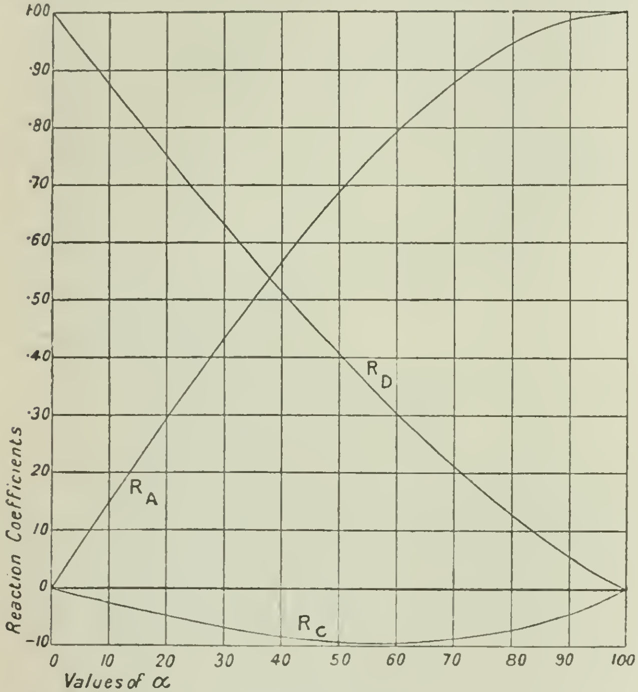


FIG. 10.

Numerical Example.

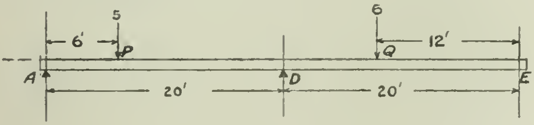


FIG. 10A.

A continuous beam of two equal spans each equal to 20*ft. carries loads of* 5 *and* 6 *tons at distances equal to* 6 *and* 12*ft. respectively from the ends.* (Fig. 10A.)

Taking first the 5 ton load, $\alpha = \dfrac{6}{20} = 0 \cdot 3 = 30\%$ $\therefore$ from the diagram $R_A = 0 \cdot 63 \times 5 = 3 \cdot 15$; $R_E = - \cdot 07 \times 5 = -0 \cdot 35$; for the other span we take $\alpha = \dfrac{12}{20} = 0 \cdot 6 = 60\%$ and reverse R_E and R_A.

$\therefore$ $R_E = 6 \times$ value of R_A in figure $= 6 \times 0 \cdot 31 = 1 \cdot 86$; $R_A = 6 \times - \cdot 09 = -0 \cdot 54$.

$\therefore$ total $R_A = 3 \cdot 15 - 0 \cdot 54 = 2 \cdot 61$ tons.

,, $R_E = 1 \cdot 86 - 0 \cdot 35 = 1 \cdot 51$,,

Positive B.M. at 5 ton load $B_P = R_A \times AP = 2 \cdot 61 \times 6 \times 12 = 188$ ton-inches.

Positive B.M. at 6 tons load $= B_Q = 1 \cdot 51 \times 12 \times 12 = 217$ ton-inches

Negative B.M. at support D $= B_D = R_A \, . \, AD - 5 \, . \, PD$
$= 2 \cdot 61 \times 240 - 5 \times 14 \times 12.$
$= 626 - 840 = -214$ ton-inches

As a check, working from the other end, we have—

$$\begin{aligned} B_D &= R_E \, . \, ED - 6 \, . \, QD \\ &= 1 \cdot 51 \times 240 - 6 \times 8 \times 12. \\ &= 362 - 576 = -214 \text{ ton-inches.} \end{aligned}$$

NUMERICAL EXAMPLE OF CALCULATIONS FOR A WAREHOUSE FLOOR FRAMED WITH CONTINUOUS BEAMS.—We will conclude the paper with an example taken from practice of the full calculations for a warehouse floor framed as shown in Fig. 11. In this case it was necessary to avoid as many pillars as possible in the building, and the arrangement shown with one central pillar only was adopted.

The floor slabs are continuous, and the extreme spans of the slabs were taken as distributing $0 \cdot 4$ of their load to the walls and $0 \cdot 6$ of their load to the secondary beams D E G , D′ E′ G′ . The other secondary beams H F J , L C M , H′ F′ J′ , were taken as carrying the full width of slab, viz., 10ft. The super load is 2 cwts. per sq. ft. The procedure is to first calculate the bending moments and end shears for the secondary beams for both spans loaded ; one span loaded (the other being unloaded) ; and both spans unloaded. The maximum and minimum reactions at the centre support are then treated as point loads for the main beam, and give respectively the loaded and unloaded conditions, the weight of the main beam itself being considered separately as explained later.

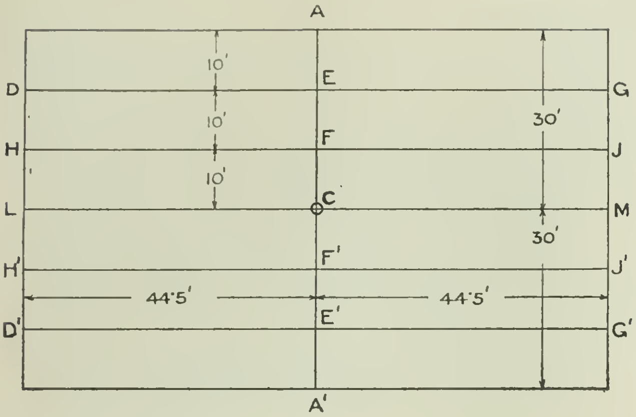


FIG. 11.

SECONDARY BEAMS.

Weight of floor per sq. ft. unloaded = 78 lb.
" " " " loaded =302 "
" beam per ft. =500 "

BEAMS D E G, D^1 E^1 G^1.

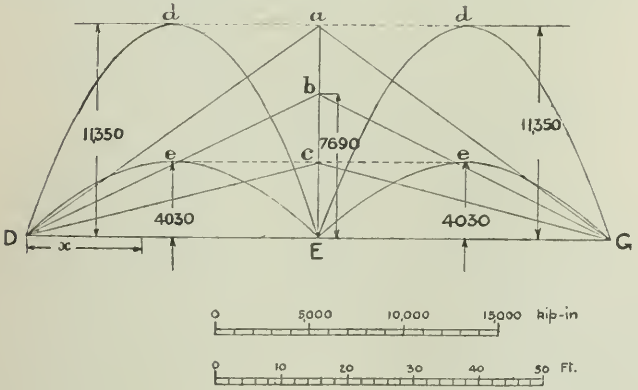


FIG. 12.

Width of floor carried = 11ft.

Weight per ft. of beam unloaded $= 11 \times 78 + 500$ lbs. = 1·360 kips*

,, ,, ,, loaded $= 11 \times 302 + 500 =$ 3·820 kips

Free B.M. Diagrams.—Loaded $\frac{W\,l}{8} = \frac{3\cdot82 \times (44\cdot5)^2 \times 12}{8} =$ 11350 kip-ins.

Unloaded $\frac{W\,l}{8} = \frac{1\cdot36 \times (44\cdot5)^2 \times 12}{8} =$ 4030 kip-ins.

∴ *Support B.M.* for both spans loaded = 11350 k.i.

,, one span loaded $= \frac{11350 + 4030}{2} = 7690$ k.-i.

Shear.—Maximum shear at centre support occurs when both spans are loaded and $= \frac{5}{8} \times 3\cdot82 \times 44\cdot5 = 106\cdot3$ k.

Min. shear at centre $= \frac{5}{8} \times 1.36 \times 44\cdot5 = 37\cdot9$ k.

Max. shear at end supports occurs when one span is loaded and one unloaded.

Maximum value $= \frac{3\cdot82 \times 44\cdot5}{2} - \frac{7690}{12 \times 44\cdot7} = 70\cdot6$ k.

Maximum intermediate B.M. is found by finding point of zero shear when one point is loaded and one unloaded.

Distance x to point of zero shear $= \frac{70\cdot6}{3\cdot82} = 18\cdot5$ ft.

$$\text{Max. intermediate B.M.} = R_D \times \frac{x}{2}$$

$$= \frac{70\cdot6 \times 18\cdot5 \times 12}{2} = 7830 \text{ k.i.}$$

Fig. 12 shows the B.M. diagrams in convenient form for the three conditions. For both spans loaded we take the two large parabolas and the base or closing line *a*; for one span loaded we take one large parabola and one small parabola and the closing line *b*; while for both spans unloaded we take the two small parabolas and the closing line *c*.

---

* 1 kip = 1,000 pounds. [Contraction of Kilo-pound.]

BEAMS H F J, L C M, H′ F′ J′—Width of floor carried = 10ft.

$\therefore$ weight per ft. of beam unloaded =
$$10 \times 78 + 500 \text{ lb.} = 1{\cdot}28 \text{ k.}$$

,, ,, ,, loaded =
$$10 \times 302 + 500 \text{ lb.} = 3{\cdot}52 \text{ k.}$$

$$\frac{Wl}{8} \quad \begin{array}{ll} \text{(loaded)} & = 3{\cdot}52 \times 44{\cdot}5^2 \times 1{\cdot}5 = 10500 \text{ k.i.} \\ \text{(unloaded)} & = 1{\cdot}28 \times 44{\cdot}5^2 \times 1{\cdot}5 = 3820 \text{ k.i.} \end{array}$$

Support B.M. for both spans loaded = 10500 k.i

,, ,, one span ,, $= \dfrac{10500 + 3820}{2} = 7160$ k.i.

Max. shear at centre $= \dfrac{5}{8} \times 3{\cdot}52 \times 44{\cdot}5 = 97$ k.

Min. ,, ,, $= \dfrac{5}{8} \times 1{\cdot}28 \times 44{\cdot}5 = 35{\cdot}6$ k.

Max. ,, end $= \dfrac{3{\cdot}52 \times 44{\cdot}5}{2} - \dfrac{7160}{44{\cdot}5 \times 12} = 65{\cdot}2$ k.

Maximum intermediate B.M. occurs at a distance from the end equal to $\dfrac{65{\cdot}2}{3{\cdot}52} = 18{\cdot}5$ft.

$\therefore$ maximum intermediate B.M. $= 65{\cdot}2 \times 18{\cdot}5 \times 12$
$= 7250$ k.i.

The B.M. diagrams for this case will be similar to those shown in Fig. 12.

MAIN BEAM A C A^1.

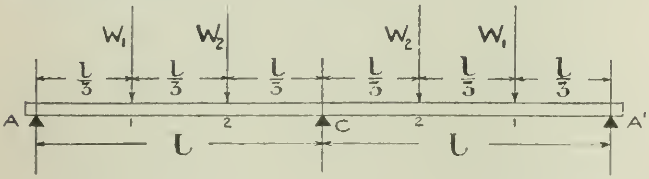


FIG. 13.

Values of W_1 and W_2 (Fig. 13) for loaded and unloaded conditions are the maximum and minimum centre reactions for the secondary beams (twice the corresponding centre shears previously computed).

We thus have— W_1 loaded = 213 kips.
unloaded = 75·8 „
W_2 loaded = 194 „
unloaded = 71·2 „
Weight of beam, each span = 34·5 „

$$\text{B.M. due to weight of beam} = \frac{W\,l}{8} = \frac{34{\cdot}5 \times 30 \times 12}{8} = 1550 \text{ k.i.}$$

Before proceeding further, we will derive formulæ for the free B.M.'s at the points 1, 2, and the supports B.M. for this condition of loading.

Each load will contribute a free B.M. diagram in the form of a △ as shown in Fig. 9 (p. 170).

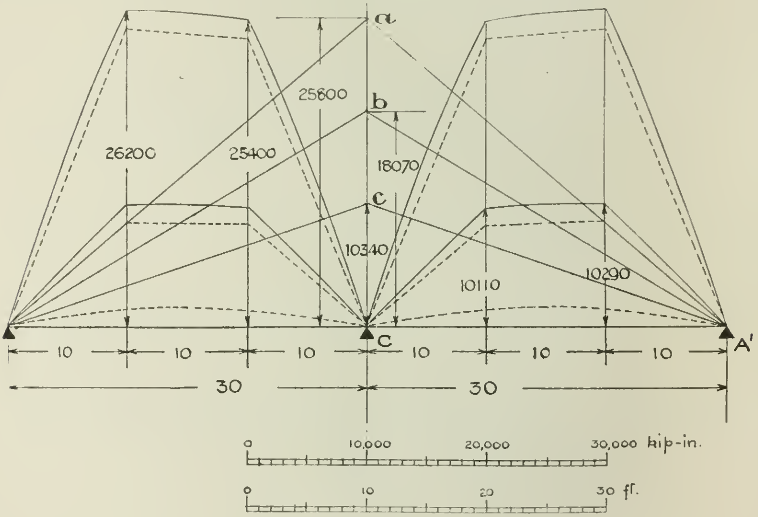


FIG. 14.

The height of the △ due to W_1 will be $W_1 \cdot \frac{l}{3} \cdot \frac{2\,l}{3} \div \frac{l}{2} = \frac{2W_1\,l}{9}$;

its area A will be $\frac{2\,W_1\,l}{9} \cdot \frac{l}{2} = \frac{W_1\,l^2}{9}$ and the distance y of its centroid from the point A will be $\frac{4\,l}{9}$ (*cf.* p. 170, putting $a_1 = \frac{l}{3}$

$\therefore$ Ay for this △ will be equal to $\frac{W_1\,l^2}{9} \cdot \frac{4\,l}{9} = \frac{4\,W_1\,l^3}{81}$

The height of the A due to W_2 will be $\frac{2\,W_2\,l}{9}$; its area A will be $\frac{W_2 l^2}{9}$, and the distance of its centroid from the point A will be $\frac{5\,l}{9}$

$\therefore$ A y for this $\triangle$ will be equal to $\frac{5\,W_2\,l^3}{81}$

$\therefore$ from the theorem of three moments, since $B_A = B_A{}^1 = 0$, we have—

$$4\,B_c\,l = 6\left\{\frac{4\,W_1\,l^3}{81\,.\,l} + \frac{5\,W_2\,l^3}{81\,.\,l}\right\}2$$

$$B_c = \frac{l}{27}\left(4\,W_1 + 5\,W_2\right)$$

The free B.M. at the point 1 will be equal to $\frac{2\,W_1\,l}{9} + \frac{1}{2} \cdot \frac{2\,W_2\,l}{9}$

$$= \frac{l}{9}\left(2\,W_1 + W_2\right)$$

and that at the point 2 will be equal to—

$$\frac{l}{9}\left(W_1 + 2\,W_2\right)$$

If the loads are each equal to W_1 the support B.M. comes equal to $\frac{W\,l}{3}$, and the free B.M. comes also equal to $\frac{W\,l}{3}$, so that the maximum intermediate B.M. comes equal to $\frac{2\,W\,l}{9}$

Putting in the numerical values for our particular case, we have—

Loaded condition.—Free B.M. at 1 due to point loads

$$= \frac{360}{9}(426 + 194)$$
$$= 24{,}800 \text{ k.i.}$$

Free B.M. at 2 due to point loads $= \frac{360}{9}(213 + 388)$

$$= 24{,}000 \text{ ki..}$$

Centre B.M. $= \frac{360}{27}(852 + 970)$

$$= 24{,}300 \text{ k.i.}$$

Adding the centre B.M. of 1550 due to the weight of the beam, we have—

Total centre B.M. $= B_c = 25{,}800$ k.i.

Unloaded condition.—Free B.M.. at 1 due to point loads

$$= \frac{360}{9}(151 \cdot 6 + 71 \cdot 2)$$
$$= 8910 \text{ k.i.}$$

Free B.M. at 2 due to point loads $= \frac{360}{9}(75 \cdot 8 + 142 \cdot 4)$
$$= 8730 \text{ k.i.}$$

Centre B.M. $= \frac{360}{27}(303 + 356)$
$$= 8790 \text{ k.i.}$$

.˙. adding as before the centre B.M. of 1550 due to the weight of the beam, we have—

$$\text{Total centre B.M.} = B_c = 10{,}340 \text{ k.i.}$$

.˙. centre B.M. for the case in which one span is loaded and the other is unloaded $= \frac{25800 + 10340}{2} = 18{,}070$ k.i.

The free B.M. at the points 1 and 2 will be equal to $\frac{W\,l}{9} = 1380$

From these results the B.M. diagrams of Fig. 14 are obtained in similar form to those of Fig. 12. For both spans loaded we take the two large curves and the base or closing line *a* ; for one span loaded we take one large curve and one small curve, and the closing line *b* ; while for both spans unloaded we take the two small curves and the closing line *c*.

The maximum intermediate B.M. occurs when one span is loaded and one is unloaded and is equal to $26{,}200 - \frac{18{,}070}{3} =$ 20,200 k.i.

Load on Central Pillar.—The maximum reaction contributed from earth side on to the pillar C from the main beam will be $\frac{W_1}{3} + \frac{2\,W_2}{3} + \frac{B_c}{l} + \frac{1}{2}$ weight of beam $= 71 + 129 + \frac{25{,}800}{360} +$ 17 = 289 kips. From each side of the secondary beam the reaction will be $\frac{5}{8} \times 3 \cdot 52 \times 44 \cdot 5 = 97 \cdot 8$ kips.

.˙. total load carried by central pillar $= 2\,(289 + 98)$
$$= 774 \text{ kips.}$$

Conclusion.—Although no attempt has been made in this paper to present novel methods of calculation for continuous beams, it is hoped that the explanations given will be of some assistance to members of this Society in performing the calculations involved in practice in the design of continuous beams

Much useful work may be done in the compiling of the tables for the bending moments occurring in continuous beams of different spans for varying conditions of loading. The most complete tables of this kind known to the author are contained in a publication in German entitled, " Interpolierbare Tabellen zum Raschen Auftragen der Einflusslinien für Momente und Scheerkrafe, by Gustav Griot, published by Schultness, Zürich. Useful tables for equal spans are given in Mr. Burnard Geen's book upon *Continuous Beams in Reinforced Concrete* (Chapman and Hall, Ltd., London).

DISCUSSION.

The President, in proposing a vote of thanks to Mr. Andrews, said that he would not abuse his prerogative by entering into a detailed discussion of the paper. He would indeed confess that he could not do so, but he might usefully allude to one or two points. He could not help feeling that, while they were apparently indebted to a German source for some authoritative calculations dealing with this subject, their attention was absorbed at the present time by German calculations of another character which were producing effects contrary to those aimed at in the paper, and which resulted in anything but " safety." The author, notwithstanding Zeppelin raids, had rendered a great service by devoting his attention so closely to what appeared to be an intricate subject.

He would also like to remark upon the introduction of new and imported terms which had no traditional value or obvious meaning, such as the word " kip." He would commend to their attention the question of standardising notation and terms such as were required in a paper of that sort.

The question of standard notation led them to the question of the decimal or metric system of calculation, and it might be interesting to consider whether the use of the metric system would not simplify formulæ and calculations, such as those presented in the paper. He was struck by the example given at the end of the paper of the calculations for a warehouse floor. His experience of work of that kind was limited and somewhat out-of-date, but he remembered that when he had to deal with such problems, floors were usually formed of rolled steel joists, the dimensions and strength of which were taken from a manufacturer's list, and no elaborate calculations were made on account of such joists being " continuous beams."

The paper gave him an impression that, the use of rolled steel joists supported at several points, might involve stresses of considerable importance which it would be dangerous to neglect. In any case the use of " rule-of-thumb " methods was objectionable especially among the younger members of the profession. Rule-of-thumb methods prevailed when he was a student and were fatal to progress and involved serious risks of danger on the one hand, and of extravagance in regard to the weight and cost of the materials used on the other. The author had presented a difficult subject in a clear manner, and as it was one of considerable importance he was sure the vote of thanks would be cordially supported.

Prof. Henry Adams said, that although the subject of the paper might be a little abstruse to the general engineer, it was, nevertheless, one under daily consideration by structural engineers. When he first studied the subject he took the case of a uniformly loaded lattice girder with two equal spans, and made a series of stress diagrams, assuming, first, that the central support took no load, and then gradually increasing the load upon it until it took all the load. In doing this he found that when five-eighths of the total load was carried by the central support, the stresses were at a minimum. This gave ocular demonstration of the fact that nature always chose the course that involved the least expenditure of energy. In constructing bending moment diagrams he preferred the form that he then sketched on the black board. For a beam carrying a uniformly distributed load over two equal spans, he first drew a parabola over the whole length equal in height to $\frac{WL}{8}$ where W was the total load and L the double span. Then whatever portion W^1 of the load W was carried by the central support a triangle was drawn with a height of $\frac{W^1L}{4}$, showing in a very simple manner how the positive bending moment was reduced by the central support. When the support carried five-eighths of the total load the stresses were at a minimum. This form of diagram gave a much clearer insight into what was happening than the form given by the author.

Mr. Allan Graham said, that with beams continuous over two or three spans, and under two or three systems of loading, the bending moments will vary accordingly as the adjoining spans are loaded or unloaded, and it is necessary to ascertain the condition of loading which induces the maximum stresses and thoroughly to understand the resulting negative and positive bending moments. It might not be so necessary to do this in designing steelwork continuous beams, from the fact that the tensional and compressional stresses were equal in that material, and that a failure on the part of the designer to appreciate the change from compression to tension in the beam would probably not lead to serious trouble, either flange being equally able to take compression or tension. Any such failure on the part of a designer in reinforced concrete would surely end in disaster. The beams had to be so designed that while the compression stresses were taken by concrete, steel rods had to be inserted to take the tension stresses, both on the underside of the beam and the top of the beam over the supports on continuous beams. If sufficient steel were not provided in the proper places to meet the change in stress, cracks would appear and possibly failure.

It might appear that there was a great deal of elaboration in the examples illustrating the paper, but he was certain that Mr. Andrews was able to get his design out by the aid of a slide rule just as quickly as any rule-of-thumb man, and the result was that he was able to put the material exactly where it was required and to omit it where unnecessary, all tending to economy in design.

By working out beams continuous over two or three spans under various systems of loading of spans, a summation bending moment curve can be plotted giving the maximum bending moments at any point in the beam, the positive bending moments being plotted above a datum line and the negative moments below. By inspection it was easy to place the steel exactly where it was required.

He thought that the paper was very useful, especially as reinforced concrete now had the " whip-hand " over steelwork owing to the War.

Mr. H. Kempton Dyson said, formulæ for continuous beams had been looked at askance for many years by engineers who were not acquainted with higher mathematics and, consequently, could not quite see how to apply the results. Worked examples of the kind given were more likely to bring the use of such formulæ into practice than were the usual text books which did not give such details.

One of the features of Mr. Andrews's work as a writer of books was that he had shown how to apply the engineering knowledge obtained by a number of men who had been working for many years at the subject of the theory of elasticity. The author had shown the most up-to-date application of the formulæ for continuous beams. He (the speaker) had seen a good deal of work on the subject, more especially in connection with reinforced concrete designs where continuous beams were used more than with any other structural material, and he thought that the author's methods were excellent, being much shorter than those used by the majority of engineers.

The author referred to arguments against the use of continuous beams and stated why such arguments were ineffective.

For one thing, he referred to the principle of least work as the best way to derive a formula for continuous beam construction. It was remarkable that Prof. Henry Adams at so early a period had emphasised that in his writings. The foundation of much scientific work was the principle of the conservation of energy, and the principle of least work was only a variant thereof. It was obvious that, unless the work or energy expended was a minimum, there would be a certain amount of energy wasted which would conflict with the laws of nature as we understood them, and upon which the whole structure of modern science was based. They found in certain old text books arguments against the use of continuous girders, more especially in steel bridge construction, but those arguments had been refuted by the principle of least work. Probably the real objection of older engineers to the use of continuous girders was their lack of understanding of how to apply the formulæ, and the paper should remove that difficulty.

The author referred to uniform live and dead loads. It did not seem to be sufficiently emphasised that the succeeding diagrams, which gave different values, were different because they allowed for the loads moving off and on the span. The author referred to rolling loads but they were not exactly that. A distributed load might not roll ; it might be just laid upon one span and not on the whole. In a warehouse floor some bays might be loaded and others unloaded, and, to allow for that variable load, they required to design the beam for bigger bending moments at some points than would be obtained from the tables on page 167, which referred to all spans being loaded equally at the same time.

When reinforced concrete was beginning to go ahead, the Steel Combine of America sent a representative to Europe with the object of getting arguments for and against reinforced concrete. By the time the representative returned to America he was a convert to the use of reinforced concrete and made a very favourable report upon it. The Combine found that though they had been losing tonnage in beam sections they were actually selling more steel, though the increase was in the form of round rods, so they published the report in favour of reinforced concrete.

In the future, national economy would have to be studied, and the paper made for national economy because it showed how 33⅓ per cent. of steel could be saved in ordinary steel construction and in reinforced concrete construction by the adoption of continuous beams. By making diagrams like the Author showed which might appear to be elaborate they could save steel.

The paper assumed a uniforn moment of inertia for continuous beams. There had been some dispute, especially with regard to reinforced concrete designs, as to whether they ought to assume this as the bars were turned up from point to point and the beams were more allied to beams which had the steel disposed according to variation of the bending moment. A few tests had been carried out with continuous beams, and those tests seemed to warrant the use of a simple formula in which a uniform moment of inertia was assumed, but there were not sufficient data to be certain. Continuous beams in finished structures ought to be tested, and there was much to be done before one could be quite sure.

If a ferro-concrete building had to be converted for use from one purpose to another there might be difficulty. Supposing that the reinforced concrete beams had been designed, for example, without continuous top reinforcements and they wanted to impose a much heavier load, if pillars were put underneath to prop the girders it would not be like propping a steel girder where there was a top flange that would take the tension. In the example there would be no steel to take tension and consequently they would get cracks, but that difficulty could be got over. In steel structures they had to take girders out, remake, trim, and so on, and it was most costly, whereas, if they took proper precautions in altering reinforced concrete buildings, they could get good results at an economical figure.

One thing to be noticed by engineers who might be propping steel girders that were not intended to be continuous was that, in a continuous steel beam over two spans, the centre support got most of the load. It got one-and-a-quarter times the load on one span. There was a case to his knowledge, in which a light steel pillar was put under a roof constructed for a Government department in which the girder was made continuous over the top. It imposed its extra load on the stanchion which began to bend, and it had to be pulled out and another put in.

REPLY.

Mr. Ewart S. Andrews said, in reply, that he thanked the meeting heartily for the vote of thanks. It had given him great pleasure to read the paper to the meeting, and he hoped it would be of assistance. He thought it would be useful for reference ; but it was difficult to make a subject of that kind interesting to a listener who had not the opportunity of studying it in detail. It seemed to him that the question of the value of what most practical engineers called " advanced theory " in practical design would produce an excellent debate. There always seemed to be an idea on the part of practical engineers that, when anybody enunciated what they regarded as advanced theory, he was attacking their designs from the point of view of their lack of safety. It would be presumptuous to do anything of the kind. If practice showed, as it did, that practising engineers had been able to design structures with adequate safety, but calculations showed them to be unsafe structures, then the calculations were wrong. The subject should be approached from a totally different point of view, namely, saving the cost of construction, and if a saving, as a result of scientific as opposed to practical methods, could not be proved, then they might just as well beat the air. He was absolutely convinced that by the aid of scientific methods they could devise means of designing structures which would effect a great saving in cost, and therefore which would be much better designed. For that reason he was a strong champion of so-called theoretical methods. The great difficulty in the past had been that most of the advocates of scientific methods had been men entirely out of touch with practice, who had not realised the limitations which practice must enforce. On the other hand, practical designers had not listened to professors because they considered that they were unpractical, and the result was that unnecessary opposition had grown up.

He was convinced that what was wrong was lack of economy. The point was not that there was not enough steel in past structures, but that there was too much, and he would cite the London Building Act, Steel Frame Regulations, as evidence of that. It absolutely enforced wasteful designs, and he believed that the whole justification which the framers of the regulations had was that the average designer had not sufficient skill to design economically, and consequently very low working stresses had to be enforced to ensure safety. That was a very bad state of affairs, and it must be grappled with.

He agreed with Professor Adam's methods, but he thought the Professor would agree, in the light of more modern knowledge, that these methods were long, though they were excellent at the time they were introduced. The methods were based on the sound principle that where they had varying conditions of stress in a structure, the best condition, and the condition which would actually hold, would be that in which the strain energy was a minimum.

With regard to Winkler's diagrams, he had not, perhaps, made it sufficiently clear that the reason why they were needed was that, if they had a variable load, that load might be on any part of the beam at any time, and, therefore, they must consider at each point the conditions which cause the greatest stress.

With regard to a uniform moment of inertia, he had refrained from making more than a passing reference to it, because there is not sufficient known about it. He believed that the present methods were the best that could be put forward, and, from investigations which he had made, he did not think that they were far wrong in view of the fact that the moment of inertia did not change considerably. It was difficult to know exactly how far one was right in an assumption until it had been proved experimentally. All that could be said was that experiments which had been made up to the present had encouraged the view that the methods in question were the best, but no man of scientific outlook would be so foolish as to say that any view which he now held would ultimately prove to be the right view.

Mr. Burnard Geen, A.M.I.C.E., wrote saying that under the heading "Alleged Disadvantages of Continuous Beams" the author discussed the question of the uncertainty and possible danger due to the unequal settlement of the supports and stated that in the case of ductile materials such as mild steel, it would not greatly matter even if the yield point were exceeded because the material was plastic beyond the yield point, and that in the case of two continuous spans, in which the intermediate support was assumed to subside, the beam would bend when the yield point of the material was exceeded, would then get a bearing upon the centre support, remain slightly bent, and the stresses would adjust themselves practically to their *previous values* because of the principle of least work.

These statements do not appear to Mr. Geen to be correct for the following reason :—

"It is possible to measure the effect of a given amount of deflection (at the centre support) upon the stresses in a loaded girder, and it is not difficult to shew that if the subsidence reached a certain amount the material would be dangerously overstressed.

"The calculations which the Author gives in the paper are based upon the assumption that the value of EI is constant.

"(1) If we assume the section is constant then the effect of subsidence of the central support is to decrease the amount of negative BM in the centre portions of the two spans, and assuming the subsidence were of sufficient magnitude, the negative BM would vanish altogether and positive BM take its place. The Author's remarks might hold good until such time as the positive BM at the pier was equal to the negative BM originally there, the nature of the stress in the top of the beam merely being changed from tension to compression.

"(2) If on the other hand we assume that the section of the beams is designed economically and that the section varies so as to give constant stress, then the effect of any considerable subsidence of the centre support will be serious, for the beam will be called upon to carry stresses of a different nature from that for which it was designed, and greater in amount also in certain points of the beam. I do not follow the Author when he says that the material may be stressed beyond the yield-point and then afterwards continue to do useful work as before.

"The diagram which the Author gives are merely plotted results from calculations of pier moments, and the paper would have been more complete if reference had been made to graphical methods of calculation. Bidder gives a simple method of checking the accuracy of any continuous beam BM diagram by comparing the areas of the shear diagram intercepted between the points of contra-flexure and the pier, on opposite side of the pier, which must be equal if the diagram is correct.

"The following examples will make this method clear: (1) Assume the case of three equal spans with free outer ends, the centre span only being loaded with a single point load. Then, assuming any span and any point load, the BM diagram will be as shewn in Fig. 1, the positive BM being hatched from left to right downward, and the negative BM hatched from right to left downward. The corresponding shear diagram is shewn below the line and the proof of the correctness of the diagram is that the area of the shear A, hatched in vertical lines, must equal the area of the shear B, hatched in horizontal lines.

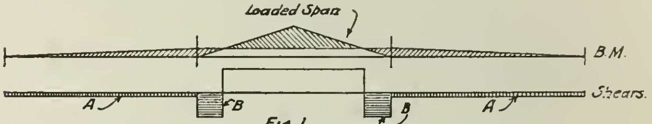


Fig 1.

"(2) Assume the case of the same three spans with the left hand side span only loaded with a single point load. Then the BM and shear will be as shewn in Fig. 2, positive and negative BM's being hatched as before. The shear areas A and B, must be equal to each other.

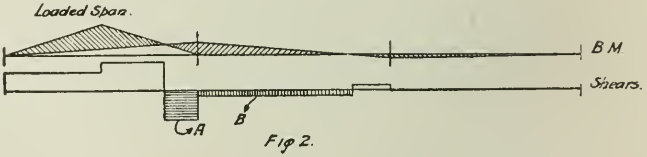


Fig 2.

"(3) Assume the case of the same three spans with two outer loaded. Then BM and shears will be as shewn in Fig. 3, the positive and negative BM's being hatched as before.

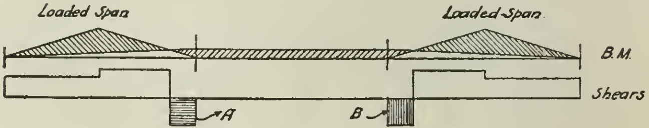


Fig 3.

"In this case, as there is no difference in BM in the centre span, there will be no shear, and consequently we must compare any two adjacent shears areas A and B.

"In the comprehensive article on continuous girders by T. Claxton Fidler (*A Practical Treatise on Bridge Construction*, Chas Griffin & Co., Ltd.) a simple graphical method is given for obtaining BM diagrams for any arrangement of spans and loading, and it must appeal to anyone thoroughly conversant with this method by reason of its simplicity and the rapidity with which results can be obtained. It is an excellent plan in the case of important calculations to employ both graphical and analytical methods in turn, and thus check the results obtained.

"The assumption of uniform flange stress, or a constant value of EI, is quite sufficient to produce a degree of inaccuracy far greater than any ordinary errors due to graphical construction, and the simplicity of the graphical method in many cases makes it preferable to elaborate analytical calculations. It will be found, by a process of trial and error, that results can be obtained rapidly almost by eye which are not further removed from the truth than the results of elaborate calculations.

"It is as well to have clearly in mind, when calculating the BM's on continuous beams, that even when the utmost elaboration of calculation has been adopted, the results are only approximate, and it is a manifest absurdity to produce results purporting to have greater accuracy than the data from which the results are deduced.

"*Re-actions.*—In the case of the members of a floor system in a reinforced concrete building (which is the most common application of continuous girders) it is of the utmost importance, if full advantage is to be taken of continuity, that the question of the increased re-actions is taken into account. This question is discussed at some length in my *Continuous Beams in Reinforced Concrete* (Chapman & Hall), where it is shewn that it is possible to have as much as 62 per cent. more load on a column where all beams are continuous than if all the beams were freely supported. It is not uncommon to find these increases ignored, but there is no justification for such omission, and the correct re-actions for any given case should be allowed for."

6th November, 1916.

Mr. PERCY GRIFFITH, M.I.C.E., President,

in the Chair.

HEATING AND VENTILATING PRIVATE DWELLING HOUSES.

By C. T. Alfred Hanssen, F.S.E., A.M.I.C.E.,
Past President, C.M.E.S.

It has often been said that it is easy to heat a house if we disregard ventilation, and that it is easy to ventilate a house if we disregard the heating, and that it is only when we try to combine heating with ventilation that our troubles begin.

In most countries in Northern Europe and America the winter temperature is much lower than in England, and the cold is too deadly and dangerous to health to permit any neglect in the heating of houses, and there it is generally the ventilation that is neglected. In England, where the average temperature of the coldest month is well above freezing point, and where there has been no really cold winter during the last twenty years, it is the heating that is neglected and the ventilation that is encouraged. Although an immense amount of coal is used for heating our houses it may fairly be stated that their average temperature is not much above that of the outside air, and although every inducement is offered to the air to enter our houses, by building them with open fireplaces and large and leaky windows—often left open during the coldest weather—thin walls, and badly fitting doors, it is really a question whether our houses are, after all, much better ventilated than those on the Continent or in America.

Air, in common with all other substances, has that inertia which compels it to remain stationary unless it is acted upon by some force that causes it to move, and it is not, therefore, sufficient to provide openings for the air to enter ; it is also necessary to provide some force to compel the air to move through the openings. If, for instance there is a considerable difference between the temperature of the room and that of the outside air, every opening, however small, will have a current of air passing through it (and if the opening be large enough to examine it by means of a candle flame it can easily be seen that there is a lower current of cold air entering the warm room and an upper current of warm air leaving it.) A fire in an open grate will cause a column of warm air to rise through the chimney, and in this manner a large volume of air may be drawn through a room, but it is by no means certain that this air will *ventilate* the room. If the incoming air is colder than the air of the room it will probably sink down to the floor level, flow along the floor to the chimney, and pass out of the room without removing or displacing the vitiated air at the breathing level of the room.

The difficulty of effective ventilation is therefore a double one: first, of causing the air to enter in such a way that it is not felt as a draught, and, secondly, of distributing the entering air over the whole room in such a manner that it really displaces the spent and vitiated air in the room. In bedrooms that are not, as a rule, heated, it is impossible to secure effective ventilation merely by opening a window, as the ventilation stops when the room is cooled down to the temperature of the outside air.

It was stated by Mr. G. T. Beilby, F.R.S., in his evidence before the Royal Commission on Coal Supplies in 1903, that the domestic consumption of coal in the United Kingdom was 36,000,000 tons per annum. As there are about 8,000,000 separate households in the United Kingdom, the average consumption of coal is therefore about 4½ tons of coal per household. As the present average price of coal is at least 30s. per ton, this quantity of coal represents an expenditure of about £54,000,000 per annum, and if this huge expenditure neither heats nor ventilates our houses it seems high time that the question of heating and ventilation should be reconsidered.

There is a widespread idea that cold air is healthy and that exposure to cold in chilly and draughty rooms hardens us and makes us better able to avoid the colds and catarrhs that are so frequent during cold weather. This, however, is one of these half-truths that are more dangerous than falsehoods. Vigorous exercise in the open air in places where the air is free from dust and smoke is undoubtedly most beneficial to health, and in this country there are very few days in the year when such exercise cannot be taken, but that is a very different thing from sitting or standing, almost motionless, in a cold room through which a current of cold air is passing. The air of our great cities is, especially during winter, very far from being of that purity which is most conducive to health, and even where it is admitted in a sufficient quantity and properly distributed through the whole room it is only a poor substitute for the air of the sea, field and forest. When, however, this air is admitted in such a manner that it forms only a cold current at the floor level, and is allowed to rush into a yawning chimney shaft a few feet above the floor, there cannot be the slightest doubt that ventilation of this kind is wholly injurious and deleterious to health.

The quarterly returns of the Registrar-General show conclusively that a cold wave causes a very considerable increase in the death rate. Table A in the Appendix gives a few examples, first, of the severe winter of 1894-95, when the death rate from January to March rose 65·5% above that of the summer.

1913-14 was a very mild winter, still the death rate during the winter quarter rose 35·5%, and last winter, although there was no continuous frost, it rose to 55·7% above the minimum.

Foreign cities generally show an increase in the death rate during winter, but the average temperature during each quarter has not been available to the author, and he has therefore given examples only from Paris and New York. In Paris open fires are used, but as people live in flats the houses are much more substantially built, and although the winter as a rule is somewhat colder than in London, the rise in the death rate is not so pronounced. In New York the winter is much colder than in London or Paris, but as the houses there are kept warm by stoves or radiators the increase in the death rate is much less than in Paris or London. The conclusion, therefore, seems irresistible that although vitiated air undoubtedly is very bad for the health, cold air nevertheless is still worse, that during every cold wave in London as many people are killed as at the outbreak of an epidemic, and that it is a worthy object of sanitary engineers to persuade people to have their houses heated and ventilated in such a manner that the winter death rates should not be substantially higher than they are during the summer.

Ventilation.—Although the essential fact regarding the quantity of air required per person for effective ventilation is fairly well established, the quantity itself as stated by good authorities varies within very wide limits. Sir Napier Shaw, F.R.S., in *Air Currents and Laws of Ventilation* demands as a normal unit 1 cubic foot per second per head, or 3,600 cubic feet per hour, while Molesworth's Pocket Book under " Ventilation " gives 300 cubic feet per hour for proper ventilation for a healthy man. The essential fact is that the atmosphere under normal conditions contains 4 parts of carbon dioxide per 10,000 parts of air, and that this proportion should not be unduly increased. The average quantity of air inhaled by an adult is about 16·6 cubic feet per hour, and the exhaled air contains 4·5 per cent. of carbon dioxide, or 450 parts per 10,000. The point in dispute is the quantity of CO_2 which may be allowed in the air of a room over and above the normal quantity of 4 parts per 10,000. If an excess of only 2 parts per 10,000 can be permitted then the quantity of fresh air required is $(16{\cdot}6 \times \frac{450}{2} =)$ 3735 cubic feet per hour, but if, as others maintain, it is quite safe to go up to an excess of 25 parts per 10,000 then only $(16{\cdot}6 \times \frac{450}{25} =)$ 300 cubic feet per hour are needed. The essential point in all systems of ventilation is that the incoming fresh air should be uniformly distributed throughout the whole room and should, as far as possible, displace the vitiated air in the room, and for this purpose the incoming fresh air should have approximately the same temperature as the air in the room, as otherwise convection currents will cause it either to rise to the ceiling if it is warmer, or to fall to the floor level if it is colder than the rest of the air in the room. Under ordinary conditions the air exhaled from the lungs will by virtue of its higher temperature, rise towards the ceiling although its high percentage of carbon dioxide makes it heavier than air of the same temperature. There is a critical point at about 80°F. when the exhaled air no longer rises but remains stationary at the breathing level of the room and, therefore, increases the difficulties of efficient ventilation.

The specific heat of air at constant pressure is 0·238 and one British thermal unit of heat will, therefore, raise ($\frac{1}{0\cdot238}=$) 4·2 lb. of air 1°F. The volume of 1 lb. of air varies from 12·4 cubic feet at 32°F. to 13·1 cubic feet at 60°F. and at this latter temperature 1 B. T. U. will, therefore, heat about 55 cubic feet of air 1°F. The cost of heating a liberal supply of air to a moderate temperature is not, therefore, very heavy, and if suitable apparatus is provided for this purpose it is quite practicable to supply the full quantity of air demanded by Sir Napier Shaw at a very moderate cost.

The cost of heating the air can be estimated when we know the average temperature of the outside air, the proposed temperature of the house to be ventilated and the volume of air to be introduced into the house.

An average family consists of six persons and supposing them to require 3,600 cubic feet per head per hour, an average house should have a supply of 22,000 cubic feet of air per hour. To introduce this air into the house by means of open windows and open fires is not only a very clumsy method but it is during the winter also a very expensive one. We may hope that one of the first results of national re-organization may be an abundant supply of cheap electric power and that this power may be obtainable at a rate of one penny per Board of Trade unit. A well designed fan with an efficient electric motor supplying the above quantity of air will then work 24 hours per day for about $1\frac{1}{4}$d. or 38s. per annum, and will save a great deal more than this value of coal.

For the purpose of heating and ventilating our houses, the year in this country may be divided into two seasons, namely, 4 months of summer when heating is not necessary, and eight months of winter when artificial heat is required.

The average temperatures during these two seasons are given in *Whitaker's Almanack* for 1913 for the period of 64 years from 1841 to 1905 as follows :—

June	30 days	at	59·4° F.
July	31 ,,	,,	62·7° F.
August	31 ,,	,,	61·5° F.
September	30 ,,	,,	57·2° F.
Summer Average ...	122 ,,	,,	60·2° F.
October	31 days	at	50·0° F.
November	30 ,,	,,	43·5° F.
December	31 ,,	,,	39·9° F.
January	31 ,,	,,	38·6° F.
February	28 ,,	,,	39·5° F.
March	31 ,,	,,	41·5° F.
April	30 ,,	,,	47·3° F.
May	31 ,,	,,	53·1° F.
Winter Average ...	243 ,,	,,	44·2° F.

If the whole house is heated it may be assumed that an average temperature of 55°F. will be sufficient, that is the bedrooms and corridors should be 50°F., and the sitting rooms 60°F. There should, therefore, be an average increase in the temperature of the incoming air of (55·0 — 44·2 =) 10·8°F. One B. T. U. will raise 53·3 c. ft. of air from 44·2 to 45·2, or, 1°F., and taking the thermal value of 1 pound of coal at 14,000 B.T.U., and the efficiency of the heating apparatus at 80 per cent., the coal consumption during the season will be

$$\left(\frac{5{,}832 \text{ hours} \times 22{,}000 \text{ cub. ft.} \times 10\cdot8^\circ\text{F.}}{53\cdot3 \text{ cub. ft.} \times 14{,}000 \text{ T. U.} \times 0\cdot80 \times 2{,}240 \text{ lb.}} = \right) 1\cdot04 \text{ tons}$$

of ordinary good coal. The heating apparatus must, of course, be arranged in such a manner that it can do the maximum work equal to at least three times the average, and it should be as far as possible self-regulating so that the air should not be overheated during spells of exceptionally mild weather.

It is only by such a complete separation of the ventilating system from the heating system that both can be effectively controlled during all the various conditions of the weather. Some simple system of washing the air should be provided for the amount of dust and dirt contained in town air is astonishing, and it would save a great deal of dusting and house cleaning if this dirt could be prevented from entering our houses.

Where the air supply is admitted to the room at a moderate temperature slightly cooler than the temperature of the room itself, and with an initial velocity of not more than two feet per second, the inlet openings should be of ample size, adjustable according to the number of persons present in the room and at the breathing level or about 4 ft. 6 in. above the floor. For ordinary rooms the outlet openings may be much smaller and as all impurities as a rule rise towards the ceiling they should be there and may conveniently be arranged as adjustable outlet-openings into the chimney-flue.

Heating.—The most convenient and most sanitary fuel for heating a house is undoubtedly gas, but in order to have gas heating as a practical possibility the cost of gas must be very materially reduced. One pound of coal yields about 14,000 B.T.U., and a ton of coal, therefore, yields 31,350,000 B.T.U., while the calorific value of a cubic foot of gas be taken at 535 B.T.U. A ton of coal is, therefore, equivalent to 58,700 c.ft. of gas and with gas at 3s. per 1,000 c. ft., this is equivalent to coal at £8 16s. 1d. per ton. Gas is, therefore, at present far too expensive for continuous heating and can be used only for cooking and temporary heating of rooms used on special occasions.

If producer gas were added to the present supply, and the mixture used exclusively for heating, distributed more continuously under higher pressure, and with an increased velocity in the mains it would be possible to distribute it at such a price that it could compete with coal, say at 9d. or 1s. per 1,000 cubic feet of equivalent heat value. The benefit of this to the community would be enormous. There would be an entire elimination of smoke from the atmosphere and a consequent improvement in the sanitary condition of our towns and cities, the heating and ventilating arrangements would be under perfect and automatic control, and in every household the hard drudgery, done mostly by women, of carrying coal and ashes, lighting fires in the morning, and stoking them every hour of the day, would be entirely abolished, and at the same time all the valuable by-products such as coal tar and sulphate of ammonia, which now poison the air we breathe, would be made available for industry and agriculture. The universal use of gas for heating and cooking is, therefore, one of the most pressing public needs.

We cannot hope to reduce the present quantity of fuel required for heating any given building to a certain temperature unless we first ascertain how the heat now used for this purpose is distributed. In testing the economy of engines and boilers, the great point is to give an exact account of the heat generated by the fuel, the heat utilized and the heat lost.

A large number of experiments have been made with domestic fires, but it does not appear that any heat balance sheet has been made, and although it is evident that great losses occur it is not clear from these experiments what becomes of the heat and why the heating effect is so small.

Some very careful and interesting experiments were carried out for The Coal Smoke Abatement Society by Mr. Alfred S. E.

Ackermann, B.Sc. (Eng.), A.M.I.C.E., and Dr. J. S. Owens, A.M.I.C.E. The best and most economical result was found with an open grate of the D.O. Boyd " Hygiastic " type which burned 3¾ lb. of coal per hour when heating a room of about 4,000 cubic feet capacity. The total calorific value of the coal was 55,350 B.T.U., and this raised the temperature of the room to 59°F. when that of the outside air was 38°F., and that of the air entering the room from an adjoining passage was 41°F. A volume of 9,738 cubic feet of air per hour was drawn from the passage and went up the chimney with a velocity of 6·85 feet per sec., and at a temperature of 100°F. The heat used for warming this air during its passage through the room was 3,780 B.T.U., or 6·83 per cent. of the total heat evolved from the coal, and the heat used for heating the flue gases from 59°F. to 100°F. was 7,749 B.T.U., or 14·0 per cent. of the total heat. The remaining heat, 43,821 B.T.U., or 79·17 per cent. of the total, is given as radiated to the walls of the room, drying and heating them. It is evident that if the walls of a room were heated they would communicate their heat to the air of the room and that this would show itself by an increased temperature, and where this is not the case it is certain that the heat escapes through the walls and windows which are far more permeable to heat than is generally supposed.

The heat losses from buildings have been very carefully tested on the Continent and the Author has reduced the heat loss coefficients from the best official continental tests and put them together in table B. Mr. R. J. Durley, B.Sc., Ma.E., M.Inst.C.E., in his paper on *The Central Heating—and Power Plant of McGill University, Montreal* (see Proc. Inst. C.E., Vol. CLXXXVIII, p. 219) mentions that these heat-loss coefficients have been found to give very uniform and reliable results, and as they are considerably higher than those given in English text-books, they should be carefully studied.

The conductivity of a wall is for all moderate temperatures exactly proportional to the difference between the inside and outside temperatures and it is for brick walls approximately inversely proportional to the square root of the thickness of the wall. According to the figures given in Table B., the heat-loss co-efficient for brickwork and concrete is very nearly

$$k = \frac{1{\cdot}957 - 0{\cdot}0131\,h}{\sqrt{h}}$$

where k = loss of heat in B.T.U. per square foot per hour per 1°F. difference of temperature between the inside and outside air for walls facing S. & W.

and h = thickness of walls in inches.

10 per cent. must be added to this value for a wall facing E. S.E. and S.W., and 15 per cent. for walls facing N.N.E. and N.W.

To ascertain the radiation from an ordinary sitting-room, some approximate tests were made in a room with a floor area of 221 square feet and a height of 9 ft. 6 in., having a total capacity of 2,100 cubic feet. The room was heated with an "Artesse" anthracite stove burning day and night through the whole of last winter. The coal consumption varied from 16 lb. to 25 lb. for 24 hours, according to the temperature of the outside air. During the 16 hours per day, when the room was occupied, the temperature was kept as nearly as possible at 60°F., and during the night the fire was banked up with 4 to 5 lb. of coal, the air supply was reduced and the temperature fell during the night to about 50°F.

During the coldest days of this year, when the outside temperature fell to 30°F., the coal-consumption during the day was about 1¼ lb. of anthracite nuts per hour. Taking the thermal value of the coal at 15,000 B.T.U., the heat generated was 18,750 B.T.U. The windows were closed and the air supply for ventilation was taken from the corridor where the temperature was about 45°F., and through the leaks round the windows. The ventilation certainly did not come up to Sir Napier Shaw's standard and as nearly as could be estimated the change of air was 8,000 cubic feet per hour, and there were complaints of "stuffiness" when more than two persons occupied the room.

The heat balance is shown in the following Table I :—

TABLE I.

Description of exposed surface.	Area of exposed surface. sq. ft.	Difference of temperature ° F.	Heat-loss coeff. in B.T.U. per sq. ft. per hour per 1° F.	Loss of heat per hour in B.T.U.
Outside wall 13½in. thick facing South	127	30°	0·51	1,943
,, ,, facing East	70	30°	0·56	1,176
Inside walls, 4½in. thick ...	276	15°	0·83	3,436
Floor boards on joists ...	221	30°	0·30	1,989
Ceiling	221	15°	0·42	1,392
Windows	50	30°	1·84	2,760
Door	19	15°	0·74	211

Heat losses due to conduction of heat through walls etc., B.T.U. = 12,907

Heat used for ventilation $\frac{8000 \text{ cu. ft.} \times 15 \text{ B.T.U}}{55}$ = 2,181

Total expenditure of heat, B.T.U. ... ... = 15,088

The total quantity of anthracite coal used for the season was two tons, or an average of about 20 lb. per diem, and the efficiency of the stove was $\left(\frac{15{,}088 \times 100}{18{,}750}\right) = 80{\cdot}5\%$. The heat used for warming the air was only 14·5 per cent., all the rest of the heat being lost as far as this room was concerned, although the heat lost through the inside walls was useful as it raised the temperature of the corridor and adjoining rooms. Of the remaining heat 52·1 per cent. is dissipated into the outside air through the walls, floorboards and windows and the remaining 33·4 per cent. of the heat radiated into the room, escaped to the other parts of the house.

Dr. Owens' tests do not show the amount of heat radiated from an open fire either of coal or gas, and the Author is not aware of any reliable radiation tests carried out with coal fires. With gas fires, however, a great many tests have been carried out by the two great London gas companies, and it seems certain that from an ordinary open gas-fire about 45 per cent. of the total heat of the gas will be radiated into the room, according to the latest bolometer tests.

The temperature of an open fire is greatly reduced by the excessive quantity of air passing through it, and this causes incomplete combustion. When coal is used the radiation varies according to the state of the fire and when fresh coal is put on a great deal of unburnt coal in the form of soot is deposited in the chimney. Soot and unburnt gas escape into the atmosphere without producing heat, and it may be taken for certain that not more than 20 per cent. of the heat of the coal is radiated into the room from an open coal fire.

It is this very low efficiency of the open fire together with the high conductivity of the walls of an ordinary dwelling-house that makes it so difficult and expensive to heat it during cold weather, and which raises the death-rate during winter and afflicts 90 per cent. of the survivors with the various illnesses and ailments due to exposure to cold air.

If, therefore, our houses are to be efficiently and economically heated it is first necessary to devise some form of heating apparatus acceptable to the tastes and habits of the British public that will produce a cheerful and pleasant heat without allowing four-fifths of the heating value of the fuel to go up the chimney and secondly to prevent the heat that has been generated being uselessly dissipated into the outside air.

If the whole house is to be heated the distribution of heat is different from that for heating a single room, as in the former case only the outside walls need to be considered as conducting the heat. We then get for each degree difference of temperature the following losses from an ordinary semi-detached nine-roomed dwelling house.

TABLE II.

Heat Losses through Outside Walls, Windows, Floors and Upper Ceiling per Hour per 1° F. difference of Temperature.

Description of Exposed Surface.	Area of exposed surface. sq. ft.	Heat-loss coeff. in B.T.U. per sq. ft. per hour per 1° F.	Loss of heat per hour, B.T.U.
13½in. walls facing East	110·8	0·56	62·0
,, ,, ,, South and West...	315·0	0·51	160·6
9in. wall ,, East	276·5	0·73	201·9
,, ,, ,, South and West...	1116·5	0·66	736·9
,, partition wall between the two houses	957·0	0·60	574·2
Windows facing East...	173·5	2·02	350·5
,, ,, South and West ...	115·5	1·84	212·5
Doors ,, East...	15·0	0·81	12·1
,, ,, West	17·5	0·74	13·0
Floor of house above ground level at ground floor	677·0	0·30	203·1
Top ceiling of house	677·0	0·42	284·3

Total heat-losses per hour per 1° F. temperature ... = 2811·1

Heating air for ventilation when the air is taken from the outside and heated in a special heater $\frac{22,000}{53\cdot3}$ B.T.U. = 413·0

Heat expenditure in B.T.U. per hour per 1° F. temp. = 3224·1

To heat such a house during the whole of the cold season from an average outside temperature of 44·2°F. to an average inside temperature of 55°F., that is to raise its temperature through an average of 10·8°F., would require the following expenditure of heat :—

Heating ... 5,832 hours × 2811 × 10·8° F. = 177,058,800 B.T.U.
Ventilation ... 5,832 ,, × 413 × 10·8° F. = 26,013,000 ,,

Total heat per season B.T.U. ... 203,071,800 ,,

That is, if we would attempt to heat an average suburban house to the very moderate temperature of 55°F. during the whole of the cold season with open fires having an efficiency of 20 per cent., then each house would want a coal supply of $\left(\frac{203,071,800}{14,000 \times 0\cdot20 \times 2240} = \right)$ say 32½ tons per annum, while if it is done with a good system of central heating having an efficiency of 80 per cent. it would require about 8⅛ tons of coal per annum. To heat a house by means of a number of open fires is, therefore, a task which is beyond the capacity of the average householder, and as central heating installations are expensive to install and somewhat difficult to regulate they are not suitable for the English custom of living in small and separate houses. Hence the heat insulation of our houses is of great importance and in most continental countries, and also in America this point is carefully attended to, as the walls of the houses are much thicker, the space between the floor joists is, as a rule, filled with non-conducting materials, such as loam and straw, and the windows are double glazed, and in the towns people almost invariably live in flats which greatly reduces the external wall surface. The quantity of fuel used for heating a flat in a town like Petrograd where the winter cold is very severe, is, therefore, surprisingly small, birch wood is used almost exclusively, and the house-owner generally includes the supply of birch wood in the rent and delivers it daily to each tenant, so that it is unnecessary to store it in the flat. The wood is used in a glazed tile stove, a massive structure about 5 ft. by 3 ft. in section and 9 ft. high and provided internally with flues which lead the flue-gases to all parts of the stove and heat the whole of it to a temperature that seldom exceeds 100 to 120°F. The fire is only kept up a few hours every day until the whole mass of brickwork is heated, the air supply is then cut off by means of a damper, and the stove remains warm during the rest of the 24 hours and gives out a very pleasant and uniform heat during the whole time. Such stoves are quite unsuitable for coal fires as the internal flues would continually be blocked by soot, but if a cheap supply of gas were available a modified form of the Russian stove might become popular in England. Such stones should be constructed in front of the present fireplace, of ornamental glazed tiles, and say 6 ft. wide by 9 or 10 ft. high, the front should be closed by an air-tight door with mica windows, the fire should be of an incandescent type and the air supply adjustable by hand, while the gas supply should be varied by means of an automatic regulator to keep the temperature of the room uniform. Such a stove would utilize 80 to 90 per cent. of the heat of the gas, it would give the cheerful glow of the open fire, while the upper heating surface, owing to its large area, would heat the room when raised to a very moderate temperature and would lend itself to any form of decorative effect that might be desired. The reason for limiting the air supply is that an unlimited air supply reduces the temperature, causes incomplete combustion of the fuel and the products of combustion pass away at so low a temperature that their heating value becomes inappreciable at a very short distance above the fire itself. A high thermal efficiency can be obtained only when the air-supply is reduced to the practical minimum.

The system of heat insulation to be adopted should be one that can be used for existing houses without any excessive expense. Slag-wool appears to the author to be almost an ideal substance for the purpose as one inch of slag-wool is as good an insulator as a foot thickness of brickwork. It is, moreover, fire-proof, sound-proof, and vermin-proof, and is at the same time a fairly cheap material, the pre-war price was £4 10s. per ton which contains 200 cubic feet, so that a layer 4½ inches thick would cover 530 square feet per ton and, therefore, cost about two pence per square foot of external wall surface, and if made in large quantities this price could, probably, be reduced. At the above price a suburban dwelling-house as described above could have the whole of its external walls, partition wall, ground floor and upper ceiling effectively insulated, equivalent to about 4 ft. 6 in. extra thickness of brickwork at a cost of about £35. For new houses the walls should be built with a hollow space filled with slag-wool during building. Slag wool should also be placed between the joists of the floor and above the ceiling. For existing houses slabs of slag-wool may be attached to the inside of the walls. One inch slag-wool slabs will retain 60 per cent., two inches will retain at least 70 per cent., and four and a half inches will retain over 80 per cent. of the heat now wasted.

As over 21·3 per cent. of the heat lost by conduction passes through the windows it is of great importance that these should be more carefully fitted and that they should have double sashes.

A house fitted in this manner would not only be warm and comfortable in the winter but also cool during the summer, for the same insulating material which prevents heat losses from within during the winter would prevent the entrance of heat from without during the summer. It would, further, be practically sound proof and all the distressing noises, inseparable from great cities, and which so frequently disturb the rest of those that are unwell or indisposed, would be kept out of the house.

There would also be a great reduction in the domestic work. Not only would the lighting and stoking of fires be abolished, but dust would be prevented from entering and a great deal less dusting, washing and house-cleaning would be required. If the heat losses are reduced 80 per cent. the fuel used for heating the whole house to a comfortable temperature would actually be less than the fuel now used for heating one or two rooms in the very imperfect manner it is done at present.

The heat losses from an insulated house are shown in Table III.

The fuel expenditure would, therefore, as compared with Table No. II., be reduced to about one-third for heating and ventilation, and while the cost for heating the whole house with open fires without insulation would be 32 tons of coal per season, this could be reduced to 8 tons per season with a more efficient system of heating, and it could be further reduced to less than three tons of coal per season if the house were properly insulated.

TABLE III.

Outside walls, windows, doors, floors and ceilings.	Area of exposed surface in sq. feet.	Heat-loss coeff. in B.T.U. per sq. ft. per hour per 1° F.	Loss of heat per hour in B.T.U.
13½ in walls facing East	110·8	0·112	12·4
,, ,, ,, South and West	315·0	0·102	32·1
9 in. partition wall between 2 adjoining houses	957·0	0·120	114·8
9 in. walls facing East	276·5	0·146	40·4
9 ,, ,, ,, South and West ...	1,116·5	0·132	147·4
Windows facing East (double) ...	173·5	0·890	154·4
,, ,, South and West (dble)	115·5	0·810	93·6
Doors facing East	15·0	0·810	12·1
,, ,, West	17·5	0·740	13·0
Ground floor of House	677·0	0·06	40·6
Top ceiling of House	677·0	0·08	54·2
Total losses of heat by conduction through walls per 1° F. difference of temperature per hour. ...		=	715·0
Heat used for incoming fresh air per hour	$\frac{22,000}{53\cdot3}$	=	413·0
Total heat expenditure per hour per 1° F. difference of temperature ...			1,128·0

It would, therefore, other things being equal, be possible to save nine tenths of the coal now wasted in inefficient heating and ventilation and at the same time render both highly efficient and more sanitary.

The general adoption of the remedies proposed in this paper would at the same time purify the atmosphere of our towns and cities and would save endless labour, worry and trouble in the households, make domestic service far more attractive than it is at present, and at the same time give to agriculture and industry those raw materials which are greatly needed but which, at present, serve only to pollute the atmosphere.

The Author is aware that extensive structural alterations in existing houses are not possible before there is a general demand for them and before tenants have found that the increased rents which they necessitate are amply covered by the decreased expenditure on fuel, and by the sanitary and domestic gains accruing from them. All such improvements are, unfortunately, much hindered by the present system of municipal taxation, which inflicts a heavy quarterly fine on those who build commodious, substantial and well-equipped houses, while it deals most leniently with the jerry-builder whose houses allow the minimum amount of domestic comfort.

The proposed improvements must, therefore, at present, be confined to new houses of the better class, and to existing houses occupied by their owners, and they can become general only when the public has been taught to appreciate their value.

TABLE A.

Table Showing Quarterly Fluctuations in Temperatures and Death Rates of Various Towns.

	April. May. June.	July. August. September.	October. November. December.	January. February. March.
London, 1894-95.				
Mean Temperature of Quarter	53·3°	58·6°	46·4°	35·2°
Death rate ... per 1,000	17·4	15·9	16·6	26·0
Increase above minimum ...	9·5%	0·0	4·4%	63·5%
London, 1913-14.				
Mean Temperature of Quarter	54·5°	60·2°	47·8°	42·5°
Death rate ... per 1,000	13·3	11·8	14·1	16·1
Increase above minimum ...	12·7%	0·0	19·5%	35·5%
London, 1914-15.				
Mean Temperature of Quarter	54·9°	62·2	46·5	40·8
Death rate ... per 1,000	13·1	13·3	15·3	20·6
Increase above minimum ...	0·0	1·5%	15·3%	55·7%
Paris, 1894-95.				
Death rate ... per 1,000	21·7	17·9	18·1	26·4
Increase above minimum ...	21·2%	0·0	1·1%	58·6%
Paris, 1913-14.				
Death rate ... per 1,000	16·7	13·5	15·9	19·1
Increase above minimum ...	23·7%	0·0	17·8%	41·5%
New York, 1894-95.				
Death rate ... per 1,000	21·9	22·2	17·7	23·7
Increase above minimum ...	23·7%	25·4%	0·0	34·0%
New York, 1913-14.				
Death rate ... per 1,000	14·2	12·4	14·0	15·6
Increase above minimum ...	14·5%	0·0	12·9%	25·8%

TABLE B.

TABLE OF HEAT-LOSS CO-EFFICIENTS, *i.e.*, Heat lost per 1°F., difference of temperature between the inside and outside air, per square foot of exposed surface in B.T.U. per hour.

Description of Wall.	Partition Walls.	Walls facing S. & W.	Walls facing E.S.E. and S.W.	Walls facing N. N.E. and N.W.
½ brick, 4⅜ in. thick ...	0·83	0·91	1·00	1·05
1 ,, 9 ,, ,, ...	0·60	0·66	0·73	0·76
1½ ,, 13⅝ ,, ,, ...	0·47	0·51	0·56	0·59
2 ,, 18¼ ,, ,, ...	0·38	0·42	0·46	0·48
2½ ,, 22⅞ ,, ,, ...	0·32	0·36	0·40	0·41
3 ,, 27½ ,, ,, ...	0·27	0·31	0·34	0·36
3½ ,, 32⅛ ,, ,, ...	0·24	0·28	0·30	0·33
4 ,, 36¾ ,, ,, ...	—	0·25	0·28	0·29
4½ ,, 41⅝ ,, ,, ...	—	0·22	0·24	0·25
5 ,, 46 ,, ,, ...	—	0·20	0·22	0·23
Concrete wall, 1½ in. thick ...	—	1·34	1·48	1·54
,, ,, 2 ,, ,, ...	—	1·25	1·38	1·44
,, ,, 3 ,, ,, ...	—	1·09	1·20	1·25
,, ,, 4⅜ ,, ,, ...	—	0·95	1·05	1·09
,, ,, 9 ,, ,, ...	—	0·67	0·74	0·77
,, ,, 13⅝ ,, ,, ...	—	0·51	0·56	0·59
Sandstone wall, 13⅝ in. thick ...	—	0·75	0·83	0·86
,, ,, 18¼ ,, ,, ...	—	0·65	0·72	0·75
,, ,, 22⅞ ,, ,, ...	—	0·58	0·64	0·67
,, ,, 27½ ,, ,, ...	—	0·52	0·57	0·60
,, ,, 32⅛ ,, ,, ...	—	0·47	0·52	0·54
,, ,, 36¾ ,, ,, ...	—	0·43	0·47	0·50
,, ,, 41⅝ ,, ,, ...	—	0·39	0·43	0·45
,, ,, 46 ,, ,, ...	—	0·35	0·39	0·40
Limestone wall, 13⅝ in. thick ...	—	0·86	0·95	0·99
,, ,, 18¼ ,, ,, ...	—	0·76	0·84	0·87
,, ,, 22⅞ ,, ,, ...	—	0·68	0·75	0·78
,, ,, 27½ ,, ,, ...	—	0·62	0·68	0·71
,, ,, 32⅛ ,, ,, ...	—	0·56	0·62	0·65
,, ,, 36¾ ,, ,, ...	—	0·51	0·56	0·59
,, ,, 41⅝ ,, ,, ...	—	0·47	0·52	0·54
,, ,, 46 ,, ,, ...	—	0·43	0·47	0·50

TABLE B.—*Continued.*

WINDOWS AND DOORS.

	Facing S. & W.	Facing E. S.E. and S.W.	Facing N. N.E. and N.W.
Single windows with single glazing ...	1·84	2·02	2·12
,, ,, ,, double ,, ...	1·29	1·42	1·48
Double windows	0·81	0·89	0·93
Single skylight	1·94	2·14	2·23
Double skylight	0·83	0·91	0·96
Doors, average value	0·74	0·81	0·85

ROOFS.

Felt, zinc, copper or slate laid on boarding	0·78	—	—
Tiles on laths	1·81	—	—
Tiles on laths with boarding and plaster...	0·59	—	—
Concrete slabs with felt and plaster ...	0·96	—	—

FLOORS AND CEILINGS.

	Floors.	Ceilings.
Beams, insulating material and boards	0·13	0·18
Floors laid above ground, joists and boards	0·30	0·42
Concrete slabs	0·66	0·66
Plaster ceilings 2 in. thick	—	1·07

DISCUSSION.

The President, in proposing a vote of thanks to the Author, said that the point in the paper which appealed to him most was the suggestion that gas could be used much more generally than at present for heating houses. He was a shareholder in several gas companies, and he was anxious to see that ideal reached as soon as possible. Owing to the high price of coal and coke and the difficulty of obtaining them, he was installing additional gas-fires in his own house, but the author's suggestions went a great deal beyond this, and he (the President) had been trying to imagine what the result would be if he asked his landlord to give him air-tight or double windows or to insulate the walls. However, they were present that evening as engineers rather than as tenants of defective houses, and he felt that the discussion of ideals, however apparently unattainable, was useful and interesting in the extreme.

He might, perhaps, draw a humorous picture in connection with the author's proposal. Imagine a stove of somewhat formidable dimensions in the modern small-roomed flat placed in front of the ordinary chimney-breast obliterating the overmantel and the clock, the inhabitants of the flat abandoning the use of the room in favour of the stove. He could hardly think, however, that the author intended his suggestion to be applied to modern houses.

The author's ideals were, however, faced by two very difficult and almost immovable things, namely, British sentiment and British traditions. If, however, some public action could be taken in the direction indicated by the author, he felt sure that the result would be very satisfactory, and that they would all feel more than ever grateful to the author for his suggestions, however Utopian they might seem at the moment. He had every confidence in proposing a hearty vote of thanks.

Mr. Walrond said that his old friend Mr. Hanssen had read a very interesting paper and had given them ideals up to which to work, and matters for thought and consideration. On p. 190 of the paper he referred to the Registrar-General's quarterly returns showing the effect that cold weather had on the death rate. He thought that the table could only be taken as showing in a very general way that cold weather did increase the death rate. He would like to ask Mr. Hanssen on what principle he had selected in every case the quarter with the lowest death rate as the one on which to estimate the percentage increase for the coldest quarter. When the Registrar-General's returns showed that the death rate for any given year was lowest in the quarter April to June that quarter was chosen by the author as his datum, but when in another year the lowest death rate occurred in the quarter July to September, then the author based the percentage increase on the return for July, August, September. Of course the result of this was to give the highest possible percentage increase for the cold quarter, namely January to March. He thought that a more rational method would have been to take as a basis not the lowest quarterly death rate, but the death rate in that quarter the average temperature of which was nearest the temperature suggested by the author as best for a dwelling house, namely 55 degrees. The returns for London given in Table A. show that the temperature for April, May and June fulfils this condition, and by taking the death rate for this quarter as a basis it will be found that the rise in the death rate in January to March, 1895, was 49·4 per cent. instead of the author's 63·5 per cent.; that in 1914 it worked out at 21 per cent. instead of 35·5 per cent.; and that last winter which was a mild one the percentage increase, namely 55·7 per cent. was considerably higher than in the very severe winter of 1894-95.

Another important point was that the author seemed to think that the increase in the death rate was accounted for by people sitting indoors in cold rooms. He thought that consideration must be given to the effect of bad weather out of doors when people got wet and cold. He feared that, even if all the proposed improvements could be introduced into houses, there would still be a substantial increase in the death rate in winter weather.

With regard to ventilation the author takes the case of a house for a family of six persons and makes provision for its ventilation on the basis of 3,600 cub. ft. of air per head per hour. Apparently when the family were congregated at dinner the whole of this air would be delivered into the dining room but if afterwards some of them went into the drawing room a due proportion of air would have to be switched off from the dining room and diverted into the drawing room.

He did not know how far the " Russian " stove would be applicable. The author said that the fire should be of an incandescent pattern with mica windows. If the stove were used in the same way as in Russia, it would be alight for a few hours in the morning and then turned out, but it was really in the evening that you wanted the pleasant aspect and ruddy glow of a fire.

If the heat losses could be reduced it would be a great advantage. The slag wool that he had seen was a very soft material, and if a layer $4\frac{1}{2}$ inches thick were put on the face of the wall of an existing house, and papered over, a slight blow or even pressure would be sufficient to damage the paper. It was proposed that in new houses the slag wool should be placed in hollow walls during building, but there would be considerable difficulty in keeping the walls dry, as they were being carried up, and if the slag wool were very moist it would make the house damp and cold, as there was very great difficulty in getting a wall dry that had once got wet.

On p. 201 the author spoke of a saving of nine-tenths of the coal now wasted in inefficient heating, but that was assuming the use of 32 tons of coal per season in an average suburban house —an amount which no one ever did use. Taking his own figures the saving to be effected by insulating a house with slag wool would be one-third and not nine-tenths. He, the speaker, did not profess to be an expert on gas, but it was possible that owing to economies necessitated by the War a cheaper method of producing gas might be found, and if that was the case, and gas could be obtained at a third of the present price, he thought that the system which Mr. Hanssen had suggested ought to be a promising one.

Mr. F. Dye said that he had little adverse criticism to offer but would ask the Author if he would modify the comparative costs of the coal and gas which were given. With gas appliances they could rely on a working efficiency of from 75 to 100 per cent., which meant that three-quarters or the whole of the heat obtained from the gas could be got into the place that was to be warmed. There were few coal or coke burning appliances that had a working efficiency of 75 per cent., the figure for the coal grate was very much lower.

It had to be acknowledged that gas, when used continuously all day, or day and night, cost more than solid fuel. This, however, depended on the cost of the gas, and in Halifax, before the War, gas was supplied for purposes other than lighting at a shilling a thousand cubic feet. There were large buildings there centrally heated by radiators which had gas boilers working at a satisfactory cost. Until a few years ago gas fires produced a certain amount of radiant heat, but the greater part of their heat was afforded by high temperature convection. We now had gas fires with an efficiency of 75 per cent. A little over 50 per cent. was in the best form of radiant heat from a glowing body, 25 per cent. represented low temperature convection, and the remaining 25 per cent. went up the chimney, but was not lost as it stimulated ventilation. What was termed the "injector" ventilating principle had been introduced in some modern gas fires which provided for an amount of air going up the chimney equal to the full area of the chimney and without loss of heat.

It had been rightly said that if you warmed the entrance hall of a house you would do much towards warming the whole of the house. Certainly, whatever warmth there was in a hall a proportion of it got into every room, being drawn in by the chimneys. If a hall was warmed it would do all that the author aimed at.

He would suggest a gas-steam radiator of an ordinary type, with about a quart of water at the bottom and the gas burner underneath. The water boiled filling the radiator with steam, and when there was a pound pressure the gas was automatically cut down to just what was necessary. The appliance only required a simple gas connection, could be used without a chimney, and would give a hundred per cent. efficiency. The products of combustion came into the house, but as the combustion was perfect the products were water vapour and CO_2 both innocuous and imperceptible. CO_2 was now known to be practically innocuous in any reasonable volume. 1030 loops were installed in the new wounded wards at St. Thomas's Hospital, half of which had no flues connected to them. A month ago he (the speaker) took a Canadian officer to see the radiators. who, after the inspection, said that satisfaction has been openly expressed.

Mr. Barker said that he must congratulate Mr. Hanssen on his paper. He had brought before them very important points on many of which, he was sure, all agreed. At the same time there were points in the paper with which he did not agree. On the first page the author said that air would not move unless it was acted on by some force, and that was perfectly true. A condition of stillness in the outer air was, however, practically unknown. The average velocity year in and year out was probably between 6 and 8 ft. per second. Moving air blowing on any opening generated pressure which caused the air to flow through the opening and of necessity caused some interchange between the inside and the outside air. He had tested many rooms for the actual interchange when there was no fire and all the doors and windows were shut. They very rarely found less than half of the room air interchanged per hour when there were no visible means of ventilating. The method by which the tests were made was by burning a candle of known chemical composition and weighing the amount of candle burnt, thus deriving the amount of CO_2 introduced into the air and making successive analyses of the carbon dioxide in the interior air. He believed that that was the only accurate method of determining the actual interchange. Analysis of air from different parts of a room gave different results unless there were fans stirring the air.

According to Dr. Leonard Hill and the school to which he belonged, the principal function of ventilation was to keep the air cool and to produce what was called a " streaky " effect in the air. The chemical question of the composition of the air had very little to do with it. What conceivable difference could the CO_2 impurity of the air in a room which never exceeded say 50 parts in 10,000 make to the lungs which always contained 400 or 500 parts.

With regard to the death rate question raised in the paper, he did not think that the logic was quite above suspicion. There might be, for instance, thousands of differences between the conditions in New York and the conditions in England which might cause the increase of the death rate in Winter to be greater in this country than in America. The modern method of dealing with phthisical patients was to take them deliberately into cold air. The function of cold air was to stimulate the organs of the body to intense activity, causing an increased metabolism and enabling the patient to consume a larger quantity of strengthening food. The function of ventilation was a matter of movement of the air and its effect on the skin rather than one of chemical purity and its effect upon the lungs.

With regard to loss of heat through the windows and so on he was in complete disagreement with the statements in the paper. For the greater part of his working life, namely, the last twenty years, he had been engaged on practically nothing else but the heating and ventilating of rooms, having during that time been responsible, probably, for forty or fifty thousand of them. Throughout he had used the data adopted by Rietschel, based on experiments by Peclet and confirmed by tests of his (the speaker's) own. The result of his experience was that he found the co-efficients gave quantities about 15 per cent. too large. The experiment described on p. 196 appeared to him to leave something to be desired from the point of view of scientific method. The author heated a room of 2,100 cubic feet with an anthracite stove and assumed that the co-efficients which he had given were correct, and then, calculating the loss of heat according to his incorrect assumption, he took the difference between that calculation and the heat derived from the complete combustion of 1¼ pounds of anthracite coal and so arrived at an efficiency of the stove of 80 per cent. That was a roundabout and certainly unscientific method, and produced a result which, in his opinion, was largely inaccurate. No such stove ever had an efficiency greater than one half of the 80 per cent. with which the paper credited it.

Then the author gave 15,000 heat units as the heat required for a room of 2,100 cubic feet, but he (the speaker) had never known a room of any such size to require anything like 15,000 heat units per hour except a room in a Turkish bath. The general amount would probably be from four to five thousand, and 15,000 would raise the temperature far beyond what could be endured.

With regard to modern gas fires, he thought that the 45 per cent. mentioned by the author might very well be increased. He had tested gas fires which gave from 50 to 65 per cent., and even 78 had been claimed, but he had never seen anything as high as that, 60 being about the usual average in a good modern gas fire. Recent alterations in gas fires had not all been improvements. Some modern gas fires were works of genius and marvellously efficient. A Committee of the British Association of which he (the speaker) was a member, was now engaged in investigating among other things gas fires and the best and most economical methods of heating houses and reducing coal consumption. A large part of the loss in connection with an ordinary open fire was through the structure at the back. A great deal of the heat got through the brickwork into the next room, or into the open if the wall was an outside one. Most of the radiated heat was conducted straight away the moment that it was absorbed by the walls and very little of it got back into the room. It was surprising that so little attention had been paid to the ultimate destination of the heat radiated from such a heating apparatus as an open fire or gas fire.

Reference has been made to the difficulty of using slag wool for the purpose of insulating. His experience was that, however tightly raw slag wool was packed into a narrow space and jammed down, it sagged in two or three weeks, and that a further amount had to be introduced to fill up the space. Slag wool was no doubt of great use as an insulator, but he thought that it should in such a case as this be in the form of a paste. But whether that method would be cheap enough for practical use it was difficult to say.

He did not think that he was altogether in sympathy with Mr. Dye's advocacy of any gas device which threw the products of combustion into the air of the room. However innocuous carbondioxide and water vapour might be—and they were by no means innocuous—there was no gas from which all sulphur was removed, and sulphur in the atmosphere as well as the products of incomplete combustion of gas are not only poisonous but also produce a smell and a deterioration of fittings.

He thought that the air of a room should be heated to a degree just sufficient for comfort in very cold weather and no more. The method of heating by water radiators for slightly warming the air during the day was by far the most economical and convenient method yet invented, but the perfection of heating could only be obtained by supplementing this form of heat by radiation from a coal or gas fire or electric radiator at times when the room was to be occupied by persons desiring the maximum degree of possible comfort.

Mr. Alfred S. E. Ackermann said, that he agreed with the figures quoted by the author from the results of the experiments carried out for the Coal Smoke Abatement Society, with possibly one exception. The Author said, " The heat used for warming the air was only 14·5 per cent., all the rest of the heat being lost." He (Mr. Ackermann) did not admit that, as the heat used for warming the walls was not entirely a loss. A room with warm walls and cold air was comfortable, but a room with cold walls and warm air was not.

With regard to the waste of heat from a fire-place in an outside wall, he, as a Special Constable, had seen an excellent illustration the previous night in Golder's Green. Although the rain had been exceptionally heavy and frequent, a patch of the pavement at the side of a house was found to be quite dry, and it was not screened from the rain. Inspection showed that there was a fire-place in the wall near the dry patch. This indicated a considerable loss of heat.

The author referred to the efficiency of an open fire as 20 per cent., but he (the speaker) objected to that figure. The tests showed that only 14 per cent. went up the chimney, and that a large proportion was radiated into the walls, producing the effect previously explained.

He did not know whether what the author had called the "Russian" stove had originated in Russia, but it was a familiar feature all over the Continent, and in some cases such stoves were gorgeous works of art, and took up a good deal of space.

Mr. Ackermann said he made some careful and unusually complete tests in 1899 at the Hospital for Sick Children, London, of the warming plant in what was then the New Nurses'-Home, and some of the results obtained were astonishing, so much so that he at first doubted their accuracy. A careful search failed to discover any comparative figures by which to check his results. That is, at that date, no such complete test had previously been made, so he wrote to Professor R. C. Carpenter in America, who was very well-known in connection with such work. The Professor was unable to furnish definite figures, but said that from his experience he thought Mr. Ackermann's results were correct, and after very careful investigation and checking he (the speaker) was confident his results were correct. The tests he planned and supervised for the Coal Smoke Abatement Society many years later, though not so complete, and made by different methods, confirmed the results of the tests he made at the Hospital for Sick Children. In the H.S.C. tests the warming was done by hot-water radiators in the dining room. The hot-water was obtained from a live-steam-coil heater 300 ft. from the dining-room, the hot-water being conveyed in $1\frac{1}{2}$ in. flow and return pipes, all lagged with 1 in. of magnesia in sections (*i.e.*, not the plastic form). The principal results obtained were as follows. In considering them it must be remembered that the heated air of the room was no doubt cooled to a certain extent by contact with the colder walls, and that, consequently, the recorded temperature of the air in the room was probably a little lower than it would have been if there had been no such loss. This means that that percentage of heat directly given by the radiators to the air of the room was probably a little more than recorded, while the percentage radiated into the walls (got by the difference) would be correspondingly less :—

Per cent.

$$\frac{\text{Total heat given to air}}{\text{Total heat discharged from radiators}} = 21 \cdot 7$$

$$\text{Hence, } \frac{\text{Total heat radiated through walls and windows}}{\text{Total heat discharged from radiators}} = 78 \cdot 3$$

Per cent.

$$\frac{\text{Total heat given to air of room}}{\text{Total available heat of steam supplied to the heater}} = 10{\cdot}7$$

$$\frac{\text{Total heat radiated through walls and windows}}{\text{Total available heat of steam supplied to the heater}} = 38{\cdot}7$$

The sum of these last two quantities gives the
Efficiency of the System = 49·4

The air of the room was changed 4·1 times per hour.

Mr. Creasey objected to the Author's statement that gas at 3s. per 1,000 cubic feet, is equivalent to coal at £8 16s. 1d. per ton, as this assumed for each an efficiency of 100 per cent., whereas that of the average coal fire is about 20 per cent. and of gas fire up to 75 per cent. Gas for continuous heat did not cost five times as much as coal as the figures would seem to show. If they had gas fires throughout a house, one might be going constantly, but the remainder would only be burning intermittently. Under such circumstances the cost was in favour of gas because it could be used intermittently, whereas a coal fire could not, and would have to be kept burning when it was not wanted because it would be wanted later.

REPLY.

Mr. C. T. A. Hanssen, in reply, said that in Russia the rooms were, as a rule, very much larger than in England and he thought that a modified form of Russian stove which utilized the breast of the chimney as a radiator should be used. As far as possible, the whole of the gases that left the fire should be used for heating a building. Effective combustion is obtained only if the quantity of the air admitted to the fire is that which is chemically necessary for burning the fuel, any excess of air introduced lowers the temperature and perfect combustion is prevented. To get really good combustion there must be a closed fireplace, and he had proposed one with mica windows. Such windows were largely used in the popular anthracite stoves, and they gave a pleasant glow in the room. People should be taught to use coal or other fuel in an economical manner. With regard to cold air affecting the death rate it was generally shown on the Continent that as soon as the temperature fell below 45 degrees the death rate increased, but in Petrograd, where the houses were most substantially built and very well heated, speaking generally, the death rate during the winter was lower than during the Summer, though, unfortunately, the returns were very defective so that he could not make much of them.

The sewage which went into the river Neva and into open canals where the water was mostly stagnant, became very offensive during the Summer and affected both the air and the water supply.

With regard to New York the healthiest quarter of the year was October, November, and December, when the temperature was something like 50 degrees, which he considered the most healthy temperature, and had taken as the normal.

With regard to slag wool, he had not actually used it for house insulation, but for steam boilers he had found it excellent. It must be packed loosely and in such a way that the lower part of it does not carry the weight of that above. Several well-known firms supply slag wool panels mounted on wire netting which can be fixed on the inside of the walls instead of wall paper.

With regard to what Mr. Dye had said as to the price of gas, he thought that 3s. was a general average for the whole of London, but it was certainly possible to sell gas cheaper than that ; before the War the South Metropolitan Gas Company's price had been as low as 1s. 9d. His idea was to utilise gas coke for making producer gas to mix with ordinary gas instead of selling the coke separately, the gas being distributed at a higher velocity and under greater pressure. Power could now be obtained at a penny per Board of Trade unit, and it could be sold at an even lower price. He thought it possible to have air passed through a heater and washer so that it entered the room at a temperature about equal to that of the inside air.

With regard to fires, he liked an open fire, but he considered it very inefficient. He thought that the average open fire in modern houses did not give an efficiency of 20 per cent.

He did not think that there was the slightest danger in having the temperature in a room up to 60 or 65 degrees, though a higher temperature might be disagreeable and disadvantageous.

He thought that the values which he had given in Table B. were correct, Mr. R. J. Durley of the McGill University of Montreal, in a paper which was to be found in the Transactions of the Institution of Civil Engineers, stated that he had found these heat co-efficients universally reliable. They were used on the Continent. The results given in Appendix B. had been reduced from figures recently published by the German Government who conducted experiments in a really scientific and effective way, spending millions of pounds, where in this country we spent only a few thousands, and they might, he thought, be taken to be as nearly correct as possible.

If there was sufficient heating surface in comparison with the fuel burnt, an ordinary stove heated with coal or coke could have an efficiency of 80 per cent. or 90 per cent. He had seen stoves on the Continent with an undoubted efficiency of 90. It was all a matter of heating surface. He did not say that the system which he had suggested was the only system, but he thought that if it could be universally adopted the air of our towns would be improved, and the by-products of gas making could be utilised.

Mr. H. Alfred Roechling, M.I.C.E., wrote regretting his unavoidable absence from the meeting. The paper was, in his opinion, an interesting and valuable one, coming as it did at a time when the conviction was gaining ground that the reconstruction of life in this country after the war must be based on sound scientific foundations if we were to hope to compete successfully with other nations.

Mr. E. L. Joseph, Director and General Manager of Ozonair, Ltd., wrote saying, he would draw attention to the third paragraph on p. 197, where it was stated that " the excessive quantity of air passing through it." Surely this should have been, " over it." This was the only error he could find.

The paper as a whole was, in his opinion, a valuable addition to the literature on the subject.

With regard to the quantity of air required per person, he considered the amount of 3,735 cubic feet per hour just as excessive as 300 cubic feet is insufficient. His company usually worked on anything from 600 to 900 cubic feet per hour per person, and found that within these limits and with ozonised air, which has been cleaned, they got good results in every case.

As regards ventilation for private houses *per se*, he did not consider the subject such a serious one. The average house, so far as ventilation was concerned, was not so badly off. It was in regard to temperature that we in this country behaved so foolishly. It cannot possibly be good for one to go out of a warm room where one has been sitting for hours, and go straight into a cold room and take off the whole of one's clothing.

He has for years drawn attention to the wasteful method of heating the ordinary dwelling house. The whole house could be kept at a reasonable temperature by the expenditure of about the same amount of fuel as is usually wasted on the fire of a single room. The very simple method that he had adopted in two of the houses he had lived in was very effective. In each of these houses there was a fair sized hall, and he installed in this hall a good stove. During the cold winter months he kept this stove going day and night, and with an expenditure of quite a small amount of fuel, his house was comfortably warm and he never had any trouble from burst water pipes, etc.

December 11*th*, 1916, *at* 5.45 *p.m.*,
PERCY GRIFFITHS, M.INST.C.E., PRESIDENT,
IN THE CHAIR.

THE MINERAL RESOURCES OF THE BRITISH EMPIRE WITH REGARD TO THE PRODUCTION OF NON-FERROUS INDUSTRIAL METALS.

By C. GILBERT CULLIS, D.Sc., M.I.M.M., Professor of Economic Mineralogy, Imperial College of Science and Technology, London.

INTRODUCTION.

In times of peace, when interchange of commodities between nations is comparatively free and unimpeded, the importance of the possession and control of adequate supplies of the raw materials necessary for the production of industrial metals is not always fully realised. But in times of war, when nations are forced to rely more strictly upon their own resources of these fundamental materials, the vital importance of such supplies becomes startlingly apparent, and a knowledge as to what supplies are available becomes more than ever necessary.

The objects of this paper are to enumerate the raw materials which serve for the production of certain of these metals, to describe their geographical distribution, especially within the British Empire, to demonstrate the general position with regard to the metals considered, and to indicate in respect of which of them the Empire is or might be self-sufficing, and in respect of which it is partly or wholly dependent upon foreign supplies.

The metals which will be dealt with are copper, lead, zinc, tin, and aluminium. Nickel and manganese are omitted as being essentially ancillary to iron and steel; antimony and bismuth because of their small utilisation in the engineering industries.

The treatment is necessarily and advisedly somewhat superficial, since each of these metals would require, for its discussion in detail, more space than is here available for all of them, and because, for the general purposes of the enquiry, detail is neither requisite nor desirable.

Such tabulated statistics as are given apply to the year 1912, partly from necessity, partly by intention. War statistics are highly abnormal, besides which many are unprocurable, some of the belligerent nations having ceased to issue them since 1914. Figures for 1913 would have been preferred as being more recent, but without the assistance of the invaluable Home Office " Colonial and Foreign Statistics " for that year, the publication of which has been deferred or abandoned owing to depletion of staff, the collection and standardisation of figures from the various original sources would have demanded more time than was available, and would not have secured any very real advantage. The Imperial situation, as indicated by the statistics for 1912, if not precisely identical with that which would be shown by figures for 1913, may certainly be taken to be the same in all essentials.

The metals will be considered in the order of the value of their world's production.

COPPER.

For the last year unaffected by the war the world's production of copper was 1,002,284 metric tons. Ten years earlier it was 602,832, and twenty years earlier 310,704 tons. Between 1893 and 1913 it had increased by nearly 225%.

This remarkable growth in copper consumption has been mainly due to the development of the electrical industries, which probably absorb at the present day more of the metal than all its other uses combined, the increase in demand for it for the manufacture of copper sheet, copper castings, and copper alloys such as brass and bronze, having been small in comparison with that for electrical machinery and transmission.

This greatly augmented demand for the metal has been accompanied by a more than proportionally increased demand for the minerals from which it is extracted owing to the fact that the rich ores which were being mined a quarter of a century ago are largely exhausted, and that those now being worked carry a much lower percentage of the metal. Copper minerals are more sedulously sought and more skilfully mined and utilised to-day than ever before.

The Ore Minerals of Copper.—There are more ore-minerals of copper than of any other metal. The list which follows, while enumerating no fewer than fourteen, includes only those of major importance. Some half dozen of these, indicated in italics, are of wide occurrence, and it is from them that the greater part of the world's supply of copper is obtained.

	Name	*Composition.*	*Copper%*
Native Ores	*Native Copper.*	Cu.	100
Oxide Ores.	*Cuprite.*	Cu_2O.	88·8
	Azurite.	$2CuCO_3.Cu(OH)_2$.	55·2
	Malachite.	$CuCO_3.Cu(OH)_2$.	57·4
	Chrysocolla.	$CuSiO_3.2H_2O$.	36·1
	Atacamite.	$CuCl_2 \, 3Cu(OH)_2$.	59·4
	Brochantite.	$CuSO_4.3Cu(OH)_2$.	56·0

		Name.	*Composition.*	*Copper%*
Sulphide Ores.	Secondary.	†Enargite.	$3Cu_2S.As_2S_5$.	48·3
		†Tetrahedrite.	$4Cu_2S.Sb_2S_3$.	52·1
		Covellite.	CuS.	66·4
		†*Chalcocite*	Cu_2S.	79·8
		†*Bornite*	Cu_3FeS_3.	55·5
	Primary	* *Chalcopyrite*	$CuFeS_2$.	34·5
		Cupriferous Pyrite and Pyrrhotite.	Variable.	Variable

Of the foregoing copper ore minerals cupriferous pyrite and chalcopyrite are the most widely distributed. Indeed, they are the original minerals from which the others have been derived. The oxidised ores are confined to the upper parts of deposits where the sulphides have been altered by the action of atmospheric waters. The summit of the deposit is often entirely leached of copper owing to the formation of copper sulphate and its downward passage in solution. Below this leached zone and above the level of underground water, oxidised ores may occur in strength forming a " zone of oxide enrichment "—one of the horizons at which copper deposits often prove highly profitable.

Beneath these zones of leached and enriched oxides a belt frequently occurs which is characterised by the presence of the higher grade sulphides. These have been formed by the action of the descending solutions of copper sulphate upon the pyrite and chalcopyrite of the original deposit, and the conversion of these relatively poor sulphides into richer ones. This zone is distinguished by bornite, chalcocite, covellite, and secondary chalcopyrite, and is a second horizon at which copper deposits yield exceptionally high values. With depth, however, these rich sulphides are lost, being succeeded first by a mixture of chalcopyrite and cupriferous pyrite, and eventually by pyrite alone. This is the " zone of primary or lean sulphides."

This threefold constitution of the copper deposit, though general, is by no means invariable. It is usually best developed in regions of moderate rainfall, especially in tropical or temperate latitudes. In these the ground-water level is at such a depth as to give room for a copious accumulation of oxidised ores, and denudation, while not so rapid as to remove the ore-deposit before oxidation and leaching can be completed, is nevertheless, sufficiently rapid to keep the leached zone eroded and to continually expose new portions of the ore-body to the enrichment process.

In regions of small rainfall—and especially in tropical latitudes—where the level of permanent water is deep, and where oxidation proceeds rapidly and erosion slowly, the oxidised zone is often of remarkable depth, but is usually succeeded at once, or with only a shallow zone of sulphide enrichment, by the zone of primary sulphides. On the other hand, in regions of heavy rainfall, where the water-level is not far underground and where denudation is rapid, the sulphides of the ore-body may be eroded before oxidation can take place, and both zones of enrichment are absent or are only feebly represented. Similarly in high latitudes or other regions where glaciation has been profound, the zone of primary sulphides usually starts " at grass," the shallow enriched zones, if ever formed, having been abraded by ice erosion.

---

* Often secondary also. † Perhaps sometimes primary.

Broadly speaking, copper deposits in low latitudes are more promising than those in high. In the former the copper values of denuded portions of the deposit have been preserved and concentrated in enriched zones, while in the latter they have been carried away with the eroded material. Only deposits of large dimensions offer good prospects in the latter case, while even small deposits in the former may carry accumulated reserves of great richness. These two antithetic cases are well exemplified in the British Empire by the deposits of Australia and Canada respectively.

In some cases copper ore may consist very largely of one or more of the foregoing ore minerals, with only a small proportion of gangue. Such ores may be smelted direct—" smelting ores." But in the majority the copper minerals are scattered in such small quantity through the gangue that direct smelting is not possible. The ore has then to be crushed and dressed to provide a concentrated product—" concentrating ores " ; or if the contained copper mineral is one of the soluble oxidised ores it may be leached by a suitable solvent—" leaching ores "— and the copper recovered by cementation or electrolysis.

The copper content of an ore in bulk may in exceptional cases be high. It is more often quite low. If high it is almost invariably due to local enrichment and is likely to be of limited extent. The introduction of late years of flotation processes of concentration, as practised upon the disseminated sulphide ores of the United States, and of hydro-metallurgical methods of extraction as recently adopted in connection with the disseminated oxidised ores of Chile, have initiated a veritable revolution in the utilisation of low grade copper ores, and have brought within the scope of profitable exploitation many large deposits which have hitherto proved unworkable. Under favourable circumstances, and if worked on a sufficiently large scale, ore containing as little as 1·75 % or 2 % of copper may be worked at a profit. The presence of small amounts of gold and silver frequently facilitates the exploitation of even leaner deposits, which with modern methods of mining, separation, and smelting, may offer much larger returns in the long run than smaller bodies of high grade ore.

British Copper Fields.—The copper ores of British origin contribute a very modest proportion of the world's production. They are derived almost wholly from Australia, Canada and South Africa, the first furnishing nearly 50% of the British production, the second just under 40%, and the third rather less than 10%. Small quantities are also raised in the British Isles, in Newfoundland and in India.

British Isles.—" The copper-tin lodes of Cornwall and Devon, the pyritic deposits of Ireland, and the veins of Cumberland once made Great Britain an important producer of the metal."* A century ago the production of copper ore and precipitate was over 200,000 tons a year. It now rarely exceeds 1% of that amount. The ore raised is principally chalcopyrite. It is mined near Dolgelly in North Wales, gold and silver being recovered from it as well as copper ; it is also obtained as a by-product from the Levant and other Cornish tin mines. Cupriferous pyrite is raised in Ireland, in Meath and Wicklow counties. A small quantity of precipitate is recovered from mine waters in Anglesey and elsewhere. The output of ore and precipitate in 1912 was 1,933 tons, and 2,732 tons in 1913, the yield of metal being 291 and 421 long tons respectively. Since the beginning of the century the copper output has not exceeded 715 tons (1905), and there is little prospect of any important increase in the future.

Australia.—Formerly Australia was famous for the richness of its copper ores. These high grade ores are now produced in but small quantity, the enriched zones of existing mines having been to a large extent worked out. In the less accessible parts of the Commonwealth, however, where transport facilities are still poor or non-existent, comparatively untouched deposits occur which in the future, when development is possible, may yield important supplies of rich ore. The operations now being carried on are mainly in the low grade primary zones of the comparatively few large deposits. Nevertheless, Australia is the premier producer of copper in the Empire.

Queensland includes several copper fields, two of which are at present responsible for the major output. These are the Mount Morgan in the south-east and the Cloncurry in the north-west. In the former, which was in its early days a famous goldfield, the ore as now exposed by deep mining is a low grade sulphide yielding both copper and gold. In the latter carbonate ores occur impregnating sedimentary rocks. This field is in a remote position, and is handicapped by shortage of water and timber and by poor transport facilities. It is, however, the most productive in Australia, and being of comparatively recent development, may be expected to contain further supplies of rich ores.

---

* " Copper Deposits of the World." Weed. p. 95.

The value of the annual output of copper from Queensland rose between 1899 and 1912, from £10,000 to £1,700,000. The ores, or mattes produced from them, are largely sent to Port Kembla, New South Wales, for the recovery of refined copper.

The principal deposit in New South Wales is that which has been mined for many years at Great Cobar in the central district. The ores occur as irregular veins in sedimentary rocks of Silurian age. Oxidation has proceeded to a depth of 250ft. ; below this the sulphide ore now being worked occurs, and consists of massive pyrrhotite carrying 2-4% of copper and 2½-3 dwts. of gold to the ton and some silver. Although the deposit has been worked for a very long time the estimated ore reserves are still large.

A number of smaller mines also make useful contributions, notably the Mouramba in the same district, and the Lloyd and Cadia in the Bathurst district.

Many mines have been worked for copper in South Australia, but only a few are still in commission. The best known, and the largest producers, are the Moonta and Wallaro mines in the York Peninsula, both of which are old and deep. At Moonta the ores are associated with an acid porphyry. Veins at depth carry chalcopyrite and pyrite, but in the upper parts there was a well-marked leached gozzan followed by rich zones of oxide and sulphide enrichment. The primary ore, now being worked, was reached at 100ft. The values in copper as well as the vein width decrease rapidly with depth. The Wallaroo deposit is in slates and schists.

The Mount Lyell deposit, near the west coast of Tasmania, is probably the best known, and has been one of the most successful copper mines in Australia. The ore-body is a great lens of cupriferous pyrite carrying 2-5% of copper and occurring at the junction of schists with conglomerates and other sedimentary rocks of Silurian age. Round the margin of the lens local enrichment is indicated by patches of dark high grade sulphides. The ore-body is supposed to be a replacement of crushed rock by mineral-bearing solutions along a sheared junction.

The copper production of Western Australia is not great. Deposits are said to be plentiful, especially in the northern districts, but as the ores carry little or no precious metal, and transport is difficult as well as costly, few of them are worked. The principal producing areas are West Pilbara in the north-west and Phillips River in the south-west.

Under Australian copper deposits reference may be made to a field of recent development in British New Guinea. Production is taking place in the Astrolabe copper field on the mainland, and ores have been discovered in some of the adjacent islands. In 1912-13 1,825 tons of copper ore were exported.

The production of copper, in long tons, for the several States during 1912 and 1913 has been summarised as follows :—

	1912.	1913.
Queensland	23,157	23,457
New South Wales ...	8,881	9,397
South Australia ...	6,505	7,314
Tasmania	5,370	4,742
Western Australia ...	1,274	1,376
Rest of Australia ...	181	281
	45,368	46,567

Canada.—The copper ore contribution of Canada comes mainly from two provinces—British Columbia and Ontario. Smaller quantities are raised in other provinces, notably Quebec. The production in this latter is greater to-day than ever before, and promises to become important.

In British Columbia three producing centres may be distinguished—the Rossland and Boundary districts, just north of the United States border, and the Coast district, extending from Vancouver northwards to the Portland Canal. The second and third of these yield true copper ores, but the first ranks as a producer of gold in the first place, and only subordinately as a producer of copper.

The Rossland district is the most easterly of the three, and lies about 150 miles west of the British Columbia-Alberta line. The area has been invaded by somewhat acid igneous rocks, and the gold-silver-copper ore-bodies are genetically connected with these. The ore-minerals are principally pyrrhotite and chalcopyrite. The gold is occasionally free, but generally is included invisibly in the sulphide. The sulphides usually occur as an impregnation of the country rock, but may at times make up 50% or even 75% of the mass. The copper content is on the average about 2%.

In the Boundary district, which is some 50 miles west of Rossland, the copper ores occur along a highly mineralised belt of limestone. The ore-bodies are lens-shaped and often of great size. The ore is low-grade and consists of chalcopyrite and pyrite, with some magnetite and hematite disseminated through a self-fluxing gangue of garnet, epidote, quartz, and calcite. The primary ore crops directly at the surface, which has been heavily

---

[*] "Queensland Government Mining Journal," Aug. 15th, 1914, p. 424.

glaciated. The copper content averages not more than 1·2-1·6%, gold and silver running about $1 a ton.

The Coast district includes a number of deposits on the mainland or adjacent islands. The largest producers of ore are the Hidden Creek mine on Observatory inlet, the Britannia mine on Howe Sound, and the Marble Bay mines on Texada Island. In all cases the ores are low-grade primary sulphides, some of which carry recoverable values in gold and silver. A remarkable increase in the output from these apparently unpromising ores has taken place during the last few years.

The British Columbia annual output of copper for the years 1912-15 averaged 22,000 metric tons. In 1912 the Boundary district contributed about 65%, Rossland 5%, and the Coast mines 30% of this total. The output for the Coast district is now however, the greatest of the three. The copper content of the ores is greater than is actually recovered, losses occurring amounting to 25%. Preliminary smelting operations are conducted in Canada, but all the refining has hitherto been done in the United States. Attempts to establish refineries in Canada have recently been made, however, and electrolytic refining of copper is said to have begun at Trail.

The copper production of Ontario is mainly from the famous nickel-copper masses of the Sudbury district. The ore bodies occur along the southern outcrop of a great basin-like sheet of norite. The ore is a massive mixture of pyrrhotite and copper pyrites. The nickel and copper contents run about 3% and 2% respectively. The ores are smelted locally to a matte containing 75% to 80% of combined nickel and copper, and this is sent out of the country, principally to New Jersey, but to a small extent also to Wales, for the recovery of nickel and copper and of the contained small quantities of gold, silver, platinum and palladium. Nearly 720,000 metric tons of ore were raised in 1913, yielding some 11,750 tons of copper and 22,500 of nickel. The estimated output for the current year is 22,000 tons of copper and 40,000 of nickel.

Numerous small deposits occur in the eastern townships of Quebec around Sherbrooke. Some of these are being actively worked, and the output is now greater than for the Rossland district of British Columbia ; for 1913 it represented 1,570 metric tons of copper. The ores are pyritic with some 40-45% of sulphur, 2·5% of copper, and small quantities of gold and silver. Practically all the ore raised is sent, either raw or after some sulphur recovery, to smelters in the United States.

Africa.—The Union of South Africa contains two copper fields of importance, one in the Cape province, the other in the Transvaal. A field is being developed also in the north of Rhodesia, not many miles south of the Katanga field of the Belgian Congo. The important copper deposits of Otavi, in German South-West Africa, are referred to under foreign copper fields.

A number of well-known mines work the valuable copper deposits of Little Namaqualand in the north-west of the Cape Province. The gneiss of this region has been intruded by dykes of gabbrodiorite, and in these magmatic copper ores occur. They are generally disseminated through the dyke rock, but are occasionally concentrated into rich masses, and these are the sites of the mining operations. The ores are chalcopyrite and bornite with pyrrhotite. There are five principal mines, three owned by the Cape Copper Co., and two by the Namaqua Copper Co.

Several other copper occurrences have been recorded in the province, the most promising of which is perhaps that at Insizwa. This resembles in many respects the deposits of Sudbury, Canada. The ore is nickeliferous pyrrhotite with copper pyrites, and is found at the base of a laccolite of norite, which has been intruded into sandstones and shales. The development of this occurrence is awaited with considerable interest.

For some years copper has been obtained from the Messina district of the northern Transvaal. Ancient workings indicate the former existence of oxidised ores. The underlying zone of secondary sulphides is now being worked, the principal ore being chalcocite.. The output of the Transvaal has increased during the last two years, and is now nearly equal to that of the Cape.

The copper production of the Union of South Africa for 1912 and 1913, in metric tons, was as follows :—

	1912.	1913.
Cape (Namaqualand) ...	7,111	5,717
Transvaal (Messina) ...	692	2,116
	7,803	7,833

At Bwana M'Kubwa in the north of Rhodesia, seven miles only from the Congo border, a promising low-grade copper deposit has been developed. It is in rail connection with Beira, but is at present handicapped by high freight charges. The copper deposits of the Katanga field extend from the Belgian Congo into Rhodesia, and are being investigated by the Tanganyika Concessions, Ltd.

Foreign Copper Fields.—Some reference seems desirable to foreign fields in view of their great importance. But only the areas of large production will be enumerated.

Europe.—The most productive district is that of southern Spain and Portugal, including the famous deposits at Rio Tinto, Tharsis, San Domingo, etc. The ore is a cupriferous pyrite occurring in great lenses associated with quartz porphyries. The ore-bodies are among the largest and best known in the world.

Russia includes three copper-bearing districts of importance—the Urals and Caucasus in Europe and the Kirghiz Steppes in Siberia. The famous malachite ore of Perm came from the first, but has long been exhausted, the underlying primary sulphides now being worked. In the second district Kedabeg is the most important centre. Here primary and secondary sulphide ores are mined. The third district is probably the richest, but has not been fully developed. Very rich sulphides occur, especially in the Spassky and Yuspenssky mines. The Russian smelting works are in the two European districts.

In Germany the Mansfeld basin in Saxony, one of the oldest copper fields in the world, is still by far the most important copper area. The ore is an 18in. bed of shale charged with chalcopyrite, bornite, and chalcocite, and yielding about 3% of copper and some silver. The shale band lies at the top of a series of red sandstones of Permian age. Before the war between three-quarters of a million and a million tons of this ore were raised annually, representing rather more than 20,000 metric tons of metal. Germany raises from this and other ores about 2·5% of the world's supply of copper.

Copper is the chief metallic product of Norway. The prevailing ores are chalcopyrite and cupriferous pyrite, and are similar to those of Rio Tinto. The most important district is that of Sulitelma in the north.

Deposits of considerable value occur in Servia. The ores are primary sulphides occurring as segregations in serpentine.

Copper ores of some importance also occur in Italy, principally near Leghorn and Genoa, and in Sardinia. The Monte Catini deposit, in the first of these districts, is the largest and best known.

Africa.—Of important copper fields outside British territory there are two—the Katanga, in the Belgian Congo, and the Otavi, in German South-West Africa. The output from Katanga, which began about 1910, is increasing with remarkable rapidity now that railway transport is available and large smelteries established. The field promises to become one of the large producers of the world. The deposits are of extraordinary size and richness. The output of copper—160, 2,300, and 10,700 tons for 1910, 1912, and 1914 severally—indicates the accelerated rate of production.

The Otavi field also appears to hold out good prospects. It has the special interest of being at the present time in British possession. The deposits are " sandstones " impregnated with sulphide ores, which near the surface have been changed to rich carbonates. The value of the deposits is increased by high lead and silver values. A matte is produced carrying all three metals. The production in 1912 was 6,987 metric tons of copper, 11,257 of lead, and 11,663 kilos of silver.

Asia.—The Siberian deposits of the Akmolinsk district have already been referred to.

Japan is the greatest Asiatic producer, ranking third among the nations, and being exceeded only by the United States and the British Empire. The deposits are very numerous and widely distributed, the principal districts being in the north (Kosaka), the centre (Ashio and Hidachi), and the south (Besshi). The ores are of the sulphide type. Much skill has been shown and much success attained in working low-grade deposits formerly abandoned. The output of metal is steadily increasing. In 1913 it was 73,152 metric tons.

South America.—Chile is the richest copper country in South America, and one of the richest in the world. The copper deposits are scattered along the whole length of the country. They were formerly famous for their rich oxidised ores, including the oxides, carbonates, silicate, sulphate, and oxy-chloride. The richest of these have now been largely worked out, and the problem of utilising the low-grade oxide and sulphide bodies has been seriously taken up. Hydro-metallurgical methods have been adopted on a gigantic scale at the Chuquicamata and Braden mines, which are expected to become, in the near future, two of the greatest copper mines of the world. In the former the ore-mineral is brochantite, an almost unique sulphate of copper; and the content of metal does not exceed 2%. The Chilian copper output has been about 40,000 tons a year, but will probably become much greater when these two mines are in full operation.

The Chilian fields extend into Peru. The greatest field is that of Cerro de Pasco, situated on the Andean plateau at an elevation of 14,000ft. This mining centre is responsible for the bulk of the copper output, which may be stated in round numbers as 25,000 tons a year.

Bolivia is a comparatively small producer of copper. The most important deposits are the red sandstones with native copper of the Coro-Coro district. They are of interest geologically because of the occurrence of copper ores, as in the Russian province of Perm, at Mansfeld in Germany, and at Boleo in Mexico, in ancient sediments of desert origin.

North America.—The United States is far ahead of any other country, both as a producer and as a smelter of copper ores. Indeed, the production of copper from domestic ores alone is greater than that of all other nations combined. It is more than six times that of the British Empire.

Broadly speaking, the deposits are found in four States—Arizona, Montana, Michigan and Utah, in order of relative importance. In Arizona the well-known low-grade "porphyry ores" occur. In Montana the chief centre is Butte, famous for its veins with rich secondary sulphides. In Michigan the unique "native ores" of Lake Superior occur. In Utah the Bingham district is an important centre; the ores are replacement bodies of igneous origin, in limestone.

The total copper output of these and other states is now well over half a million tons a year.

Mexico, which was at one time the second copper producing country of the world, now contributes less than half its output of a few years ago. This is due to internal and external disturbances. Eventually, no doubt, the former rate of production will be resumed. Copper deposits are widely distributed, but the most important are in the states of Sonora and Lower California. These, owing to their remoteness from disturbed areas and to their proximity to the United States boundary, have been least affected, and the current output is largely derived from them.

Copper deposits are worked in Cuba at the El Cobre mines, near Santiago. Ore and matte are exported in considerable quantities to the United States.

World's Production and Consumption of Copper.—The following table, taken from the publications of the British Home Office (Mines and Quarries) shows the amount of copper contained in ores raised in British and foreign countries during 1912:—

COPPER IN BRITISH AND FOREIGN ORES RAISED IN 1912.
(Metric Tons.)

British.	
Australia	44,290
Canada	35,615
South Africa	8,884
British Isles	296
India	209
British Total	89,294
Foreign.	
Austria-Hungary	1,300
Belgium (Belgian Congo)	2,463
Bolivia	3,765
Chile	41,647
Cuba	2,147
France (including Algeria and French Equatorial Africa)	441
Germany	27,410
German South-West Africa	6,987

Italy	2,748
Japan	63,892
Mexico	73,000
Norway	15,240
Peru	26,970
Portugal	4,838
Russia	33,550
Servia	7,355
Spain	60,610
United States	563,943
Other European Countries	1,634
Other Countries	2,249
Foreign Total	942,189
World's Total	1,031,849

Estimates of the world's smelter production and consumption for the same year in metric tons are as follows* :—

SMELTER PRODUCTION.

United States	592,400
Japan	67,000
British Isles	63,200
Australia	44,900
Mexico	44,000
Germany	39,800
South America (other countries) ...	35,000
Russia	33,500
Chile	25,000
Spain	23,300
Canada	15,500
France	13,200
Europe (other countries)	10,900
Servia	7,400
Austria-Hungary	4,000
Italy	1,700
	1,016,800

CONSUMPTION.

United States	371,800
Germany	232,700
British Isles	144,700
France	99,800
Austria-Hungary	48,200

---

[*] "Copper Handbook." Weed. 1915.

Asia, Africa, Australia	40,400
Russia	40,000
Italy	33,600
Belgium	15,000
Europe (other countries)	10,000
America (other countries)	3,000
Holland	1,000
	1,040,200

British Situation.—It will be seen from these figures that the mine production of copper in the British Empire for 1912 was, in round numbers, 90,000 tons, or some 9% of the world's production.

The smelter production may be estimated at 125,000 tons out of a million, or 12½% ; and the consumption at approximately 175,000 tons out of the same generalised total, or 17½%.

The mine production only sufficed for slightly over 50% of our requirements, and the smelter production for just over 70%. In order to attain to complete independence of foreign sources for our supplies of copper it would be necessary to approximately double our mine production, and to increase our smelter production by some 40%.

Both of these are very remote possibilities : but the condition as regards smelting would be substantially improved if the copper ore, matte, and crude metal which are now exported to the United States from British Columbia and Quebec for the recovery of refined copper, and from Ontario for the extraction of refined nickel and copper, were dealt with to a finish in Canada itself. The Dominion is, perhaps, more fortunate than any other country in the world in its resources of water power, which are already a good deal used for smelting purposes. A probable effect of extending existing smelteries and establishing new ones would be to stimulate production of copper ore from districts where deposits of value are known to occur, but have hitherto remained unexploited because of prohibitive freight costs. The effect of the bounties now offered on copper smelted and refined in Canada from Canadian ores by the Dominion Government will be watched with interest.

The Rhodesian properties of the Tanganyika Concessions, Ltd., may become important copper producers in the future.

In the event of the transfer of German South West Africa to permanent British possession, the copper output of the Otavi field, which may be estimated at 7,000 metric tons a year, would go to improve our mine production.

LEAD AND ZINC.

Owing to the intimate way in which these two metals are associated in nature, it is proposed to consider them together in order to avoid much repetition which would otherwise be necessary.

Immediately before the war the annual production of lead was 1,142,264 metric tons. Ten and twenty years previously it had been 951,517, and 622,648 tons respectively. The increase in the consumption of lead during recent years has not been nearly as great as in that of copper and zinc. This is because no large scale new uses, such as have characterised copper and zinc, have been discovered for lead. Such increase as has taken place is due to normal expansion of uses of long standing, including the manufacture of lead sheet and pipes, lead alloys and lead pigments.

Of zinc the world's production in 1913 was 1,103,359 metric tons. Ten years earlier it was 569,971 tons, and twenty years earlier, 375,191 tons. The marked increase in the production of this metal is due not only to greater consumption for established uses, but also to the introduction of new ones. Of the large scale uses, determining the demand for zinc and its ores the most important are galvanizing, sherardizing, electro-galvanizing, the making of sheet zinc and of zinc castings, the manufacture of brass and other zinc alloys, the desilverizing of lead, the recovery of gold and silver from cyanide solutions, the discharging of colour in the dyeing of cotton goods, and the preparation of white pigments. For some of these uses zinc dust or " blue powder " is specially suitable.

The Ore Minerals of Lead.—The principal lead-producing minerals are enumerated in the table below :—

			Lead content. %
Secondary or " Oxidized Ores "	Cerussite,	$PbCO_3$	73
	Anglesite,	$PbSO_4$	68·3
	Pyromorphite,	$3Pb_3P_2O_8\ PbCl_2$	75·8
Primary or " Sulphide ore "	Galena,	PbS	86·6

The most abundant of these is galena. This is the primary mineral from which the others have been derived. Of the secondary minerals the most important is cerussite, anglesite and pyromorphite being much less commonly found in quantity. Other lead-bearing sulphides and oxidised minerals frequently occur, but have no general importance as sources of the metal.

Galena almost invariably contains silver, and usually in quantities permitting of profitable extraction. Indeed, argentiferous lead ores furnish a far greater proportion of the world's silver than the definite high grade silver minerals.

The silver content often renders possible the exploitation or ores which would be unworkable with profit if lead were the only product of value to be obatined from them. Non-argentiferous ores, such as those of South-Eastern Missouri, yield " soft lead," the argentiferous yield " lead bullion," which after the recovery of the silver becomes " desilverised lead." When argentiferous galena is converted into oxidised lead ores, some of the silver usually passes into solution and descends to the unaltered sulphide zone below. Here it is redeposited in the form of high grade silver ores, which cause a local enrichment of the deposit as regards the precious metal. In this way as the deposit is worn down by erosion, the silver values, instead of being carried away, tend to accumulate, either in the oxidised zone, or in the immediately underlying sulphide zone, and to give special richness to these portions of the deposit. This process was well exemplified by the Broken Hill Lode, which in its higher levels yielded ores of extraordinary richness. The lead itself being a somewhat inert and immobile metal is not liable to migration and redeposition.

Many galena ores carry antimony. These yield " antimonial lead," from which both antimony and lead may be recovered.

The Ore Minerals of Zinc.—Some of these have a world-wide distribution, others a restricted occurrence.

	Universal Ores.	*Zinc content.* %
" Calamine " or " Oxidized Ores "	Smithsonite $Zn CO_3$	52
	Hemimorphite $2ZnO. SiO_2. H_2O$	54·2
	Willemite $2ZnO. SiO_2$ ...	58·5
" Sulphide Ore "	Zinc Blende ZnS.	67

	New Jersey Ores.	
Zincite	ZnO.	80·3
Franklinite	$(FeMnZn) O. (FeMn)_2 O_3$	13·6—20
Willemite	$2ZnO. Si O_2$	58·5

Blende is the original and most abundant zinc mineral. It is found in the deeper and unaltered portions of zinc deposits. The " Calamine " ores have been formed by the alteration of blende and are found in those parts of the deposits which lie between the surface of the ground and the level of permanent water. By the action of atmospheric waters blende is converted into the soluble sulphate of zinc, and it is by the action of solutions of this salt upon the country rock that the "oxidised ores" are formed. But much of the sulphate solution descends into the underlying parts of the ore-body, and here coming into contact with pyrite a double reaction takes place resulting in the deposition of secondary blende side by side with the primary. In this way a zone of zinc enrichment may be formed. This accounts for the well-known fact that many deposits, which are opened up as lead or silver-lead mines, become zinc mines as deeper levels are reached, the immobile lead remaining unshifted by atmospheric waters, while the mobile zinc is largely filtered down to lower levels, where it accumulates.

When associated with argentiferous lead ores the zinc ores are usually argentiferous also, but their yield of silver is in all cases much lower than that of the lead minerals. This is interesting and contrary to expectation in view of the great affinity of zinc for silver, an affinity which is used in the desilverisation of lead bullion by the Parkes process.

It has been said that lead and zinc are almost invariably closely associated in ore deposits. This is in a sense fortunate because the same mining operations serve as a rule for the winning of both metals. Occasionally, however, lead deposits comparatively or quite free from zinc minerals occur, or zinc deposits free from lead. These are the so-called "straight ores." But in most deposits minerals of both metals are intermixed. Silver, as previously stated, is generally present also. Very frequently iron and copper sulphides occur, and these may carry values in gold. Deposits of mixed ores of this kind are of world-wide distribution. They are often of low grade, but make up for this defect by their large dimensions, and by the number of valuable elements which they contain. They are spoken of as "complex ores." The simpler bodies of these mixed lead and zinc ores, which present no great difficulty as regards the concentration of their galena and blende, have long been worked. Others like the Broken Hill deposit of New South Wales in which valueless gangue minerals of about the same specific gravity as the blende are intimately mingled with the ore-minerals, have only proved completely exploitable after prolonged investigations terminating in the adoption of flotation, magnetic, or other special separation processes. But until recently the more complex deposits, in which the ore is of very fine texture, or in which many metallic minerals are associated, have been left severely alone, attention being given in preference to available supplies of "straight ores." Within the last few years the problem of the utilization of such deposits has been seriously studied, and in a certain number of cases has been more or less satisfactorily solved, and complex ores such as those of British Columbia and Burma are being vigorously exploited. There can be little doubt that in the future, when all the values of deposits of this kind can be turned to account, they will become extremely important sources of lead, zinc, silver, and possibly also of copper and gold, as well as of sulphur for the production of sulphuric acid.

British Lead and Zinc fields.—Australia, the premier producer of copper in the Empire, also ranks first as a producer of lead and zinc. Ores of both metals are also worked in Canada and in the British Isles ; and deposits believed to have great future prospects are already being developed in Burma and Rhodesia.

British Isles.—Lead and zinc ores are mined in the Palæozoic rock of Wales, the Isle of Man, the North of England, and the South of Scotland.

In 1912 there were obtained 25,409 tons of dressed lead ore, and 17,704 of zinc. Much of the latter was exported to Belgium and France ! This fact is all the more remarkable, and discreditable to British industry, when it is remembered that practically all the zinc ore smelted in this country is imported.

Canada.—Lead and zinc ores are known to occur in many parts of Canada, but practically the whole output has of late years come from British Columbia. Here the ores have an extensive occurrence, and the number of mines, already considerable, is likely to increase. They are, broadly speaking, confined to the Kootenay district, Fort Steele and Slocan, in East and West Kootenay respectively, accounting for the major output. The ores are complex and difficult to utilize. They consist of mixtures of argentiferous galena and blende, with or without iron and copper pyrites. They were formerly exported to the United States, but the lead ores are now successfully dealt with at the famous smelteries and refineries at Trail. The zinc ores still find their way to the United States, the difficulties of treating them not having been overcome. Considerable sums have been voted by the Dominion Government for investigations, and both electrothermic, and leaching and electrolytre methods have been tried, the latter with some success. To encourage the industry until established a system of bounties has been introduced. It is believed that before long the zinc ores, like the lead, will be dealt with entirely in Canada and that the production of both will show important increases.

During 1913 Canada produced 85,978 tons of lead ore and 10,893 of zinc ore, almost all of which was raised in British Columbia. The present output is probably greater.

Australia.—The most important lead-zinc deposit in the British Empire, and also the largest yet known, is that of Broken Hill, New South Wales. This great lode occupies an elongated saddle-shaped cavity in an anticlinal fold in metamorphic rocks, the apex or " back " of the fold cropping at the surface, and forming an elevated ridge some two miles long. The oxidised minerals which were taken out in the early days consisted largely of argentiferous cerussite, and the halogen minerals of silver, together with limonite and psilomelane, all embedded in a kaolin matrix. Beneath this oxidized zone the sulphide ores were encountered. These consist of a closely intermixed granular aggregate of galena and blende, with a small amount of pyrite. Accompanying these is a gangue of garnet, rhodonite, and quartz. The galena, and to a smaller extent the blende, are silver bearing. This sulphide ore has been worked since about 1895. The content of lead silver and zinc has decreased gradually with depth, but the deposit is expected to continue a large producer for many years to come.

By concentration and separation the ore yields two chief products—lead ore with about 65% of lead, and 5% of zinc and some silver, and zinc ore with about 45% of zinc and 5% of lead. The lead ore is largely smelted in Australia into lead bullion and exported. In the early days the zinc was not collected but went to the dumps in the tailings and slimes, great quantities of which gradually accumulated. At present these are being treated by flotation and yield principally a concentrate with about 50% of zinc, 5% of lead, and nearly 10 oz. of silver to the ton. Before the war the total zinc concentrates produced approximated to 500,000 tons a year, capable of yielding not less than a fifth of the annual requirements of the whole world in spelter. Some 90% of the concentrates were exported and smelted in Germany and Belgium. Of the insignificant remainder a part was smelted in South Australia at Port Pirie, and the rest in England at Seaton Carew.

The Broken Hill deposit dwarfs all others in Australia, but small quantities of lead-zinc ores are also mined in Queensland and in Western Australia ; and occurrences of such ores in Tasmania and New Zealand have been recorded.

India.—Large and very promising deposits of highly argentiferous lead-zinc ores occur in Upper Burma. They are situated at Bawdwin in the Northern Shan States near the frontier of the Chinese province of Yunnan. They were long ago worked for silver by the Chinese, and great quantities of slags, rich in lead, occur near by. There are four isolated ore-bodies, one of which is very large. In each case the core of the ore-body is of high grade massive ore, and is surrounded by an envelope of low grade disseminated ore shading into the country rock.

The ore is complex and consists of galena, blende, and pyrite, with occasional chalcopyrite. According to variations in the proportions of these minerals the recoverable products in different parts of the ore-body are two or more of the metals lead, zinc, silver, copper. The mines are connected by rail with the port of Rangoon. It is proposed to increase the plant already installed so as to ensure an annual output of 300,000 tons of ore. The field, according to reports, promises to prove a great national asset.

Africa.—Hitherto the production of lead-zinc ores in British Africa has been insignificant. But in north-western Rhodesia a deposit—the Rhodesian Broken Hill—has been discovered, which is reported to be of great prospective importance. Large quantities of rich ore are indicated at the surface. As exposed it consists of a mixture of oxidised minerals of lead and zinc, suggesting a galena-blende aggregate at depth. The separation of the oxidised ore-minerals from one another presents difficulties which have not yet been overcome. But when a commercial process has been worked out and transport facilities have been improved, this, like the Bawdwin deposit, promises to become a valuable addition to the Imperial lead-zinc resources. The deposit is being developed, and a smeltery for lead and zinc is reported to be in course of erection.

Foreign Lead and Zinc Fields.—No more will be attempted than a passing reference to the most important.

Europe.—Germany and Spain are great producers of lead and zinc ores, the former more especially of zinc, the latter of lead. In Germany the principal deposits are those of Silesia near the Austrian and Russian borders. The ores occur in dolomitic limestones, and are largely oxidised, although sulphides are found at depth. The Spanish fields are principally in the south-central provinces and near the east coast. These are particularly rich in argentiferous lead ores, but carry also some zinc. The most important zinc centre, however, is in the province of Santander, where exceptionally pure oxidised ores occur in limestone. Italy owns rich lead-zinc deposits in south-eastern Sardinia. These also consist largely of oxidised ores in limestone, but galena and blende are both extensively mined. The lead ores are smelted in the island, but the zinc ores are exported. Owing to the disturbance of the usual market for these and Spanish zinc ores by the war, a new market is being found for them in the United States. The Laurium district in Greece has long been famous for its lead-zinc deposits. Sweden produces zinc on a considerable scale from the deposits of Ammeberg in the south. Austria and France also make notable contributions ; but Norway, Belgium and Russia (in Europe) produce little domestic ore.

North America.—The United States, even before the war, was the largest producer of ores of both lead and zinc. Since the commencement of hostilities her output, especially of the latter, has advanced by leaps and bounds. Fully a dozen states are large contributors, but the most important are Missouri, Idaho, Utah, and Colorado for lead, and Missouri, Colorado, Montana, an Wisconsin for zinc. Zinc ores of a unique type are largely worked at Franklin, New Jersey. Much zinc ore which before the war was exported to Germany now makes its way to the United States.

The total output of lead from domestic ores in 1912 was 392,517 short tons, and of zinc 323,907. This constituted rather more than 30% of the world's production.

Rich deposits of lead and zinc ores occur and have been extensively mined in Mexico, which at one time ranked among the greatest producers of lead, if not of zinc. Owing to revolution within, however, and war outside, mining operations have been very adversely affected, and the output is much reduced.

South America.—This continent is as yet a consumer of lead and zinc rather than a producer, Bolivia and Peru alone making small contributions.

Asia.—Important deposits of lead-zinc ores occur in China, and some are actively worked. The largest are those of Yunnan. Some of the ore is smelted in the country, but much of it, after dressing and concentration, has been exported to Germany for smelting. German interests in the Chinese lead-zinc deposits are considerable, and no doubt attempts will be made after the war to extend and consolidate them.

Productive deposits also occur in Indo-China.

Japan has deposits, especially in the province of Hida. Modern plant for dressing, separation, and smelting has been put down, and the production of lead and zinc is rapidly expanding. At Kosaka " an electrolytic process has been devised for the recovery of the metallic zinc from the mixed sulphide ore, and also from the slag, and is reported to be a success."*

In the Semipalatinsk district in Siberia a very large deposit of rich complex ore carrying values in lead, zinc, gold, silver and copper is being developed at the Ridder mine of the Irtysh Corporation. The proposal is to ship the lead and zinc concentrates down the Irtysh River to the Ekibastus coalfield, where they will be smelted to lead bullion, spelter and copper matte, which, in turn, will be shipped on to Omsk on the Trans-Siberian Railway. The deposit is reported to have great possibilities. If these are realised the position of Russia, which has hitherto been entirely dependent on other countries for lead, and very largely for zinc, will be favourably affected as regards these two metals.

World's Production and Consumption of Lead and Zinc.—The following tables show the mine production, smelter production and consumption of lead and zinc for the world for the year 1912. The first is taken from the "Colonial and Foreign Statistics" issued by the Mines and Quarries Department of the Home Office; the others from the "Mineral Resources of the United States."

---

* " Mineral Industry," 1914. p. 195.

LEAD AND ZINC IN BRITISH AND FOREIGN ORES RAISED IN 1912

(Metric Tons.)

British.	*Lead.*	*Zinc.*
British Isles	19,461	6,159
Australia	217,120	199,926
Canada	16,222	3,100
India...	8,340	—
Rhodesia	533	—
South Africa	570	—
British Total	262,246	209,185
Foreign.	*Lead.*	*Zinc.*
Austria-Hungary	19,600	7,420
Bolivia	—	1,863
China	680	1,816
France	9,980	14,620
Algeria	9,783	37,033
Indo-China	—	10,279
Tunis	24,700	16,400
Germany	77,786	240,596
German S.W. Africa ...	11,257	—
Greece	15,368	8,700
Italy	24,453	56,496
Japan	3,733	7,487
Mexico	109,720	15,550
Peru	4,050	—
Russia	1,000	11,100
Spain	170,100	60,810
Sweden	2,512	21,984
Turkey	11,000	2,110
United States	376,844	293,847
Others	432	453
Foreign Total	872,998	808,564
World's Total	1,135,244	1,017,749

WORLD'S PRODUCTION AND CONSUMPTION OF LEAD IN 1912.
(Short Tons.)

Production.

Australia	118,387
Austria-Hungary	23,589
Belgium	56,438
Canada	17,968
France	34,282
Germany	194,666
Great Britain	32,187
Greece	15,983
Italy	23,699
Japan	4,960
Mexico	132,276
Russia	1,102
Spain	205,799
Sweden	1,433
Turkey in Asia	13,779
Other Countries	13,448
United States	392,517
World's Total	1,282,513

Consumption.

Australia	11,133
Austria-Hungary	41,667
Belgium	49,493
Canada	33,069
France	115,411
Germany	255,844
Great Britain	216,381
Holland	6,944
Italy	36,376
Japan	24,030
Russia	50,265
Switzerland	7,055
Other European Countries	4,850
Other Countries	33,069
United States	394,159
World's Total	1,279,746

WORLD'S PRODUCTION AND CONSUMPTION OF ZINC IN 1912.

(Short Tons.)

Production.

Australia	2,531
Austria and Italy	21,609
Belgium	220,678
France and Spain	79,543
Germany	298,794
Great Britain	63,086
Holland	26,380
Poland	9,659
Norway	8,959
United States	338,806
World's Total	1,070,045

Consumption.

Austria-Hungary	51,588
Belgium	85,098
France	90,389
Germany	248,899
Great Britain	204,146
Holland	4,409
Italy	11,795
Russia	30,754
Spain	5,181
Other Countries	21,715
United States	340,341
World's Total	1,094,315

British Situation.—From the foregoing tables, and assuming the accuracy of their figures, it will be seen that for the period shortly antecedent to the war British ores furnished about 23% of the world's production of lead, Australia alone contributing 19% of the total and 83% of the British production.

The mines of the Empire contributed during 1912 262,246 metric tons of lead towards the world's total of 1,135,244. The consumption was 236,464 metric tons. The mines, therefore, yielded more than enough lead for Imperial requirements ; if the ores had been smelted to a finish in the Empire there would have been a small excess of metal for exportation. But the smelter production of lead was only 152,942 tons—a good deal of ore, or lead bullion, having been exported for smelting or refining in foreign countries—leaving 83,522 tons to be supplied by the foreigner. The Empire made 65% of its requirements in lead and imported the remaining 35%.

With no more than the current mine output it could be quite independent of outside sources But in order for that complete independence to be realised the existing lead-smelting industries would need to be increased by more than 50% When some of the new and promising deposits such as those of Burma and Rhodesia are further developed, the Empire could become an important exporter of lead

Turning now to zinc, it will be seen that during the same period the British Empire contributed about 20·5% of the world's mine production. The proportion of the whole furnished by Australia was 19·5%, and of the British production 95%.

The British zinc deposits yieldsd 209,185 metric tons out of a world's total of 1,017,749. The consumption of zinc was not less than 185,250 metric tons, so that in this case also if all the ores had been made to yield their metal in the Empire, there would have been more than sufficient for Imperial requirements As a matter of fact, however, the zinc ores were largely exported for treatment and only 59,544 tons of zinc metal were made in the Empire, leaving 125,700 to be provided by foreign countries, principally Germany and Belgium. The Empire made, therefore, 32% of her requirements of zinc, and was dependent on outside sources for the remaining 68%. Here again it is not the zinc deposits which are deficient, but the smelting organization. In order that the production of metal should be sufficient for Imperial requirements, an increase in existing smelting facilities of not less than 200% would seem to be necessary.

The insecurity of the present position has been brought home to us in a specially striking manner in the case of zinc because the large deficiencies in our smelter production had been made good by imports from Germany and Belgium. On the outbreak of war, or immediately after, these imports ceased, and for a period of some months, a shortage of zinc was experienced which seriously jeopardised our supply of munitions, and which would have continued to do so if we had not been able, by paying an unprecedented price, to obtain gradually increasing supplies from America. The manner in which the United States has, during the last two years, expanded her output of zinc to meet this suddenly created demand, is a high testimony to her extraordinary adaptability. Ingalls estimates that the output, which in 1913 was 320,000 metric tons, in 1915 was 451,000, and that for 1916 an output of at least 714,000 tons seems assured.

The war has, indeed, in the matter of base metals, proved America's great opportunity. She has risen to it, and it is she, rather than Germany, who will be our great competitor in the near future. But it should prove our opportunity also by necessitating a new destination for the Broken Hill ores, which, in future, should be smelted entirely within the Empire. The smelting works at Port Pirie, South Australia, produced about 2,500 tons of zinc in 1912, rather more than 4,000 in 1913, and over 5,000 in 1914. It is planned to expand the capacity to an output of 25,000 tons a year. A similar expansion of output should be effected in England. " The establishment in this country of a zinc smelting industry on a scale commensurate with its needs is most urgently required . . . . It would be an industrial victory of the first magnitude, and it would remove a peril in which this country was placed by the outbreak of war which has been all too imperfectly realised, and which should never be allowed to recur."*

TIN.

The annual consumption of tin is small in comparison with that of copper, lead, or zinc. In 1913 according to published figures† the world's production was 126,878 metric tons; a decade earlier it was 94,387 tons; and ten years before that 68,300 tons. The greater part of the output is absorbed in the tin-plate industry, and in the manufacture of tin-bearing alloys. The increase of nearly 90% in production during the 20 years quoted is due to the normal expansion of these uses, and to the fact that the total is so small—a slightly augmented world's consumption necessitating an increase which, though small actually, is relatively large.

Ore Minerals of Tin.—Tin presents a marked contrast to copper in that there is only one mineral which serves as a commercial source of the metal. This is cassiterite or tinstone, the oxide of tin containing, when pure, 78·6% of metal. A sulphide mineral stannite, tin pyrites, or bell-metal ore, is occasionally found in copper-tin lodes in small quantities, but the output of tin from it is very small. It is a sulphide of copper, tin, and iron, and contains, if pure, 27·5% of tin, and 29·5% of copper.

Not only has tin this unique restriction as regards ore-minerals, but it also has an invariable original mode of occurrence. Its home is in the peripheral portions of certain granitic intrusions, or in the adjoining parts of the invaded rocks. In all tin-bearing districts hitherto discovered this geological environment has been found. The only exceptions are those regions in which the place of the granite is taken by quartz porphyry (*e.g.*, Tasmania) or by rhyolite (*e.g.*, Bolivia). Since these rocks, however, are merely quickly cooled forms of granite magma, such exceptions are more apparent than real.

---

* Carpenter: " The Future of the Zinc-Smelting Industry in Great Britain." *Nature*, October 5th, 1916.

† " Mineral Industry," 1892-1915.

Tinstone being a very stable mineral persists when the parent rock undergoes disintegration by weathering, and thus finds its way into gravels or other detrital deposits, where it undergoes a process of natural concentration to form tin alluvials. According as the tin is sought in these or in the parent rock a distinction is made between alluvial and lode mining for tin. Tin differs in this respect from all other industrial metals, and resembles the precious metals gold and platinum.

Tin alluvials are, as a rule, superficial deposits, soft and more or less unconsolidated, and often carry the tinstone in higher proportion and freer from deleterious sulphur, arsenic or other minerals than in the parent lode. They are usually more easily and cheaply mined than tin lodes, and are consequently the first deposits to be exploited in a newly discovered tin field, the more serious enterprise of attacking the lodes being undertaken subsequently. Only in rare cases in which, as in New South Wales and Tasmania, the alluvial material has been covered by flows of basalt or other overburden, so as to be not easily accessible, does the mining of detrital tin present serious difficulties. At the present time a very large proportion, about 75% of the world's supply of tin, is obtained from alluvials. But in Cornwall and Bolivia lode mining is alone practised, and in the Federated Malay States, Australia, South Africa, and elsewhere lodes are being sought and opened up as alluvials become exhausted. In the future, lode-mining for tin will play a more and more important part.

The proportion of cassiterite in the crude ore or gravel varies widely; broadly speaking profitable exploitation is not possible if the former contains less than 1% (22 lbs. to the ton), or the latter less than 1 or 2 lbs. to the cubic yard. The ore is marketed as dressed tin ore or "black tin," the quality of which varies with the tin fields or even with individual mines. The price is affected by the presence or absence of certain prevalent impurities. The product from alluvials is generally of better quality than from lodes. A rough estimate of the value in metal is usually made on a 70% basis, but some of the lode product contains not more than 65%, while the alluvial may carry as much as 75%.

The dressing of lode tin is an elaborate and rather costly process, and generally involves considerable losses of tin ore—in some cases as much as 40% or even more. Considerable losses occur also in smelting. The total loss of tin metal in these ways is very serious, and one of the most urgent needs, affecting the full utilization of tin ore resources, is the discovery and adoption of methods by which this waste may be eliminated.

British Tin Fields. The British Empire is fortunate in its tin resources. It is in a far stronger position, both as regards mine and smelter production, in the case of this than of any other of the base metals.

British Isles.—Notwithstanding the fact that Cornwall has been supplying tin to the world for more than twenty centuries, it still takes honourable place among producers. The annual output of tin is about 5,000 tons, and there is reason to believe that if enlightened prospecting and bold development were rendered possible by adequate financial support, this could not only be maintained but materially increased. Indeed, within the last few months important discoveries of new lodes, rivalling in richness those worked many years ago, have been made as the result of the co-operation of the mine manager with wide experience with the highly trained mining geologist.

The Cornish tin ore is smelted in England, as also a good deal imported from South Africa, Nigeria, and Bolivia. These combined yield a smelter production in the British Isles of about 20,000 tons.

Malay States.—The largest and most productive tin-bearing region in the world has its centre in the Malay Peninsula, and extends northwards through Siam to Burma, and southwards to the islands of Banka and Billiton in the Java Sea. The British tin producing areas lie in the Malay States and Burma. The former contribute more than a quarter of the world's annual output, and constitute the greatest of all producers. The western States, especially Perak and Selangor, furnish the greater portion of the total output.

The ore is found in both lodes and alluvials, but the mining is, in the main, alluvial, and probably will continue so for many years. Not only has a good deal of the alluvial ground remained so far untouched, but also the operations in the past have been largely primitive in character. The more general employment of up-to-date large-scale hydraulic methods, such as have already been introduced in the Kinta district, should considerably increase the range of ground workable at a profit. Water is sufficiently abundant, except during severe drought, and its distribution and administration are in the hands of the mining department.

Lode mining is not yet very active, but is certain to play a growing part in the future. Members of the Geological Survey of the Federated Malay States have demonstrated the existence of numerous lodes along the granite margin, both in the igneous rock and in the invaded slates, schists and other sediments, and those discovered together with others doubtless to be discovered, constitute a great reserve to be drawn upon as the alluvials become gradually exhausted. The systematic prospecting of the granite peripheries should be undertaken by scientifically trained geological experts either attached to the Geological Survey or employed by enlightened and far-seeing British companies. The return for such investigations could scarcely fail to be out of all proportion to their cost, more especially since other valuable minerals, such as wolfram, which are world-wide associates of tin, are more than likely to be discovered at the same time. Hitherto the amount of wolfram recovered from the Malay States has not been large, the main supplies occurring to the north in the Burma region, in which apparently tin becomes less abundant in proportion as wolfram becomes more abundant. Wolfram is, however, a mineral which is more liable than cassiterite to destruction in the making of alluvial deposits, and there is a probability that the lodes both in the Malay States and in Burma will be found to yield a higher return of this mineral than the alluvials.

The annual output of the Malay States may be stated as about 50,000 tons of metallic tin.

India.—The tin-producing districts of India are Mergui and Tavoy in Burma. The ore is obtained from detrital deposits of various kinds, but is also extracted from the granitic parent rock. In both cases, and especially in the latter, the cassiterite is often accompanied by wolfram and other valuable minerals. The output of wolfram, stimulated by requirements for war purposes, has very greatly increased, and with it that of tinstone should increase also. In 1912 the output of the latter was equivalent to about 300 tons of metallic tin.

Practically all the tin ore obtained in the Malay States and Burma is smelted at British works in Penang and near Singapore. Ore from China, Siam, Alaska and other foreign fields, as well as from Australia and South Africa, is also smelted here. The smelter production in Malaya is therefore considerably greater than the mine production, the total being about 63,000 tons.

Australia.—Tin ore is widely but sparsely distributed in the Commonwealth of Australia. The most important fields are in Tasmania, Queensland, New South Wales and Western Australia.

In Tasmania the north-west of the island, with the Mount Bischoff mining centre, and the north-east, with the Briseis and Pioneer mines, yield more than one-half of the island's output. In the former district tin gravels were worked at one time, but have been exhausted. The ore is now taken from a complex of lodes associated with porphyry dykes, which penetrate slates and other sedimentary rocks. In the latter district the tin is won from a " deep lead " lying beneath an overburden of columnar basalt. Other well-known mines are the Anchor and Australian, which are working an extraordinarily low-grade deposit in granite by open cast methods. The Tasmanian ore is smelted at Launceston.

In Queensland there are two principal tin-bearing areas, one in the north, the other in the south just over the New South Wales border. In the former, or Herberton field, the tin ore is taken both from alluvials and lodes. The value of some of the lodes is augmented by the presence of tungsten and bismuth ores. In the latter, or Stanthorpe field, tin lodes and alluvials occur, but most of the ore is obtained from the gravels, which are skilfully worked by modern methods, particularly dredging. This area may be regarded as a northern extension of the principal New South Wales field.

The most important area in New South Wales is that of Inverell-Emmaville-Tingha immediately adjoining the Queensland boundary. The ore is obtained both from the original rock and from gravels. The alluvial deposits include " deep-leads " covered by flows of basalt, as well as ordinary surface gravels. The Australian miners have developed special methods of working detrital deposits by means of suction-pump dredges, either fixed, or floating in a pontoon, which permit of continuous powerful hydraulic operations with a very limited water supply.

In Western Australia tin deposits have been discovered and worked at a number of widely separated localities, two only of which—the Greenbushes district in the south-west, and the Pilbara in the north-west—are at present contributors of ore. Pegmatite veins traversing granite are the principal sources of the cassiterite. The ore is obtained both from these and from gravels resulting from their disintegration. A feature of interest, and possibly of future economic importance, is the occurrence of tantalite with the tinstone in the former, and of monazite in the latter.

Tin is worked spasmodically in " small man " deposits in the extreme north of the Northern Territory.

A general idea of the magnitude of the tin industry of Australia may be gathered from the fact that in 1912 the total production of tin ore concentrates was about 10,000 tons, and of this Tasmania contributed 3,700 tons, Queensland 3,250, and New South Wales 2,350. On an assumed 70% basis this represents 7,000 tons of tin metal.

Africa.—In British Africa tin is obtained from the Transvaal, Swaziland, and Nigeria. The first two districts are not expected to become large producers, but the last is believed to have considerable future possibilities.

In the Transvaal the tin occurrences of economic importance are confined to the Waterberg fields in the north-west of the province. The ore is won almost entirely from the red granite of the region or from the adjacent Lower Waterberg sedimentary rocks. Normal lodes occur, but in one district the ore-bodies assume the form of highly inclined pipes in the granite. Alluvial deposits also occur, but their relative importance is small.

The output of tin in 1912 was about 1,750 tons.

In the north-west of Swaziland tin ore occurs and is worked in lode and detrital deposits. The output of tin in 1912 was about 200 tons.

The most recently discovered British tin-field is that of Northern Nigeria. Both alluvial and lode mining are now in operation, but the former largely predominates. In 1913 more than 5,000 tons of tin concentrates were won, a substantial increase on previous years (1912, 2,886 tons). Recent developments are promising and suggest that when certain difficulties which hamper the full utilization of its tin resources have been removed the region may rank as one of the important producers of the world. The principal obstacles to a larger output are the inadequacy and cost of transport, the shortage of water, scarcity of labour, and high working costs. The supply of native carriers from mine to rail head is small and uncertain, and much delay is experienced in the delivery of supplies and the despatch of ore, by railway congestion. Water for concentration of the detrital deposits and dressing the lode material is scarce at the best of times, and may be unprocurable for weeks owing to drought. Labour for the mines is difficult to obtain, much that would be otherwise available being absorbed for porterage or in railway construction. Transport charges are high and fuel for power is expensive. Some of these difficulties will be reduced if and when projected railway extensions are completed, and the Udi coalfield is brought in touch with the mines. The possibility of an artesian water supply might be considered.

Foreign Tin-fields.—The principal producers of tin-ore outside the British Empire are the Dutch East Indies, Siam, China, and Bolivia.

The Dutch East Indian supply is obtained from the islands of Banka and Billiton between Sumatra and Borneo. These lie on a southern extension of the axis of the Malay Peninsula, and doubtless form part of the same geological province. The bulk of the ore is obtained from alluvials, but lodes have been discovered and lode-mining will play a larger part in the future. The annual output of tin is not far short of 20,000 tons.

The Siamese tin-fields lie between those of the Federated Malay States and of Burma. They form part of the same great tin-bearing belt. The deposits worked are alluvials. An output of ore averaging some 5,000 tons of tin has been maintained for many years, and recently has been increased as the result of ably-conducted dredging operations.

Tin ore is also exported from China, principally from Yunnan. This also is alluvial ore. Very little is known to outsiders of the geology and distribution of the Chinese deposits. The amount of tin exported annually is about 6,000 tons, but considerable amounts must also be produced and retained for internal consumption.

Next the Federated Malay States the greatest tin producer is Bolivia. The deposits differ in notable respects from all others in the world, especially in that the lodes occur in or in association with acid lavas, and that values in silver and bismuth accompany those of tin. The mines are situated in difficult mountainous country. The cost of import of machinery and equipment, and of export of tin and other products is high. The result is that only the larger and richer deposits can be worked under existing conditions. Many of these are extremely rich, much of the ore being coarse enough to be sent to market after the simplest kind of dressing. A very small part of the ore is smelted locally. Most of it is exported as a concentrate called *barrilla*, rated at 60% tin, to England, Germany, and France. Bolivia is one of the regions from which a considerably enlarged production may be expected as a result of more efficient mining and milling operations, and better railway facilities. The annual output of tin is between 20,000 and 25,000 tons.

Small quantities of tin ore are, or have been, obtained in Europe, *e.g.*, in Spain and Portugal, Austria, Italy, France, and Germany. The Portuguese deposits have been the subject of recent investigations, but there is no report of any substantial increase in the output.

In North America tin ore has hitherto been reported in commercial quantity from the extreme south (Mexico) and the extreme north-west (Alaska). Small quantities of alluvial tin are raised annually in the latter region, and are shipped to Singapore to be smelted. No tin deposits of importance have yet been found either in the United States or in Canada.

World's Production and Consumption of Tin.—The following tables show the world's mine production and smelter production of tin for 1912. The first is taken from the "Colonial and Foreign Statistics" for that year, issued by the Home Office, the second from "Mineral Industry" (Vol XXIII.) :—

TIN IN BRITISH AND FOREIGN ORES RAISED IN 1912.
(Metric Tons.)

British.	
Malay States	47,995
Australia	6,745
British Isles (Cornwall)	5,338
Nigeria (North and South)	3,798
Union of South Africa	1,773
India (Burma)	287
Swaziland	200
British Total	66,136
Foreign.	
Bolivia	23,168
Dutch East Indies	20,232
China	8,783
Siam	6,669
Spain and Portugal	232
Japan	198
United States	123
Indo-China	101
Austria and Italy	76
Foreign Total	59,582
World's Total	125,718

WORLD'S PRODUCTION OF TIN IN 1912.
(Metric Tons.)

Malay States	61,528
British Isles	18,938
Dutch East Indies	18,354
Germany	10,646
China (exports)	8,785
Australia	5,130
Bolivia	552
France	500
Other Countries	50
	124,483

British Situation.—From these figures it will be seen that the British Empire raised, in the year quoted, 66,136 out of 125,718 tons (or some 53%) of the world's supply of tin, and that no other nation furnished more than 20%. Further, it may be seen, that of the tin smelted 85,596 tons out of the 124,483 (or about 69%) was produced within the Empire.

The tin consumption of Great Britain for 1912 was 27,350 metric tons,* and for the Colonies about 5,150 tons, giving a total consumption for the Empire of 32,500 tons. According to this estimate our mine production was 33,636, and our smelter production 53,096 metric tons in excess of our annual requirements.

Seeing that a great deal of tin ore of foreign origin is smelted in England and in the Malay States, as well as domestic ore, British control of the metal production is very strong. In fact, our position with regard to tin is comparable with that of the United States with regard to copper.

The Bolivian output is capable of expansion, but so also is that of Nigeria. Further, the contribution of the Burmese fields may be expected to improve *pari passu* with the improvement in the wolfram output, and a very considerable increase could probably be effected from the Malay States if necessary, by the adoption of economical large scale operations.

Further, there are reasons for the view that the recovery of tin ore in Cornwall might be augmented. First, the tin lode may now be made to yield not one marketable product, but several. Some of the minerals which almost invariably accompany the cassiterite and from which it has always had to be separated by laborious and expensive dressing processes, are no longer waste products, but by-products of great value. Among these may be mentioned mispickel, copper pyrites and wolfram. The greatly enhanced price of wolfram alone should cause many lodes previously abandoned because of an indifferent tin yield to merit renewed investigation. It can scarcely be doubted that a small proportion at least of the many abandoned tin mines of this country could be resuscitated and converted into paying concerns in view of the values now attaching to the minerals other than tin which the lodes contain, and the greatly improved yield and isolation of these minerals which magnetic separation and other modern methods of dressing have effected.

Secondly, very little mining in Cornwall has been carried to a depth of more than 1,000 feet. "There are over 600 abandoned mines in Cornwall, and their average depth is under 800 feet. So that Cornwall is practically a virgin field below a level of say 900 feet."† But most of the existing mines have been raising profitable tin ore for many years from depths greatly exceeding this. Is it not reasonable to expect that, in those cases where lodes extend to depth, the zone between 1,000 and 2,000 feet may carry values of tin (and other minerals) capable of profitable recovery ?

---

* Board of Customs and Excise.

† "Tin Mining Handbook," p. 17.

And thirdly, only those lodes which crop at the surface, together with a few " blind lodes " picked up accidentally in the course of underground development, have hitherto been mined. Blind lodes other than those already located must occur in the peripheral portions of the granite or in the metamorphic aureole. Possibly there is as much tin underground in Cornwall as has been taken out. Would it not be well to call in boring methods of prospecting for these, as has been done with considerable success, in connection with other mineral deposits, in our Colonies, in the United States, and to a limited extent in our own country. The selection of promising points either at the surface or underground, and the determination of direction, might be entrusted to mining geologists with a special knowledge of tin deposits in general, and of Cornish deposits in particular. The discovery of a single strong lode would more than repay the cost of an extended investigation of this kind.

The United States recovers some tin from waste tin-plate, alloys, etc., but has hitherto depended ultimately upon metal smelted abroad, and principally of British origin. The consumption for 1912 amounted to 52,750 metric tons, or 43% of the world's production, and was larger than that of any other country. Some years ago an attempt was made to establish works in New Jersey for the treatment of Malay States tin ore ; but the prompt imposition by the British Government of an export tax upon ore shipped from the Peninsula caused the enterprise to collapse. Recently, however, with the German market for Bolivian tin ore cut off, an outlet for some of it has been sought in America, and it is reported that up-to-date smelting works have been erected and the production of metal from ore commenced. The Bolivian ore, like so much lode-ore, yields, by ordinary smelting methods, a metal too impure for tinplating. To overcome this difficulty the smelting works are reported to include a plant for electrolytic tin refining. Refined metal produced in this way and submitted to English experts has shown 99·98% of tin as against 93% in the unrefined metal,* The smelters of Great Britain are said to have selected only the best qualities of Bolivian ores, rejecting those of lower grade than 65% or with undesirable impurities, and at the same time raising their returning charges by nearly 50%, thus forcing Bolivian ore on a less exacting American market. Seeing that our methods of tin-ore dressing and smelting have been to a large extent immune from acute competition in the past, and have remained, perhaps, in a somewhat crude and imperfect condition, it behoves us to set our house in order in this matter if we wish to produce tin at the most favourable price and to retain the substantial control of the only large tin-field outside the Empire.

---

* *Engineering and Mining Journal*, January 8th, 1916.

ALUMINIUM.

A few years ago aluminium was little more than a metallurgical curiosity ; to-day it is, after iron lead zinc copper and tin, the most important industrial metal. Many believe that it is destined to rank in production second only to iron, while enthusiasts, influenced by its favourable chemical and physical properties, and by its extraordinary abundance in the earth's crust, have prophesied its eventual assumption of the first place among the useful metals.

In 1893 the world's production* was 716 metric tons ; ten years later 8,123 tons ; and in 1913 it was estimated to be 78,716 tons.

The greatly expanded industrial applications of the metal, of which this phenomenal increase is a measure, include the making of vessels for domestic, manufacturing, and military purposes, the provision of parts for air and water craft, motor-cars, railway coaches, etc., the construction of bus-bars and bi-metallic cables for electric transmission, the preparation of aluminium foil and powder—the latter employed as a metallurgical reagent, as a constituent of high explosives, and as a protective paint—and the manufacture of aluminium alloys. For these and other uses the metal is proving so valuable that an annual consumption of 100,000 metric tons is expected in the near future, if indeed it has not already been realised.

The Ore Minerals of Aluminium.—Aluminium is the most abundant of the useful metals. Indeed, next to oxygen and silicon it is the most plentiful of all the elements, constituting no less than 8% of the earth's crust. In felspars it makes up from 10% to 20% of the mineral, and in kaolin, the essential basis of all clays, it is present to the extent of 21%. The supply of aluminium in these world-wide silicates is inexhaustible, and if the metal is ever to attain to the large importance which some predict, it is from these sources that it must be obtained. But its extraction from such sources has not yet become possible on a commercial scale. Pending the perfection of such processes, the aluminium of commerce is obtained from other and less abundant materials.

The one and only ore of aluminium at present employed is the hydrated oxide bauxite ($Al_2O_3 . 2H_2O$). Pure bauxite contains 73·9% of alumina, equivalent to 39·13% of aluminium. Its actual yield, however, owing to the presence of oxides of iron, silica, oxide of titanium, carbonates of lime and magnesia, and other impurities, ranges between 40% and 70% of alumina, most commercial ore carrying between 50% and 60%, corresponding to a metal content of from 26·5% to 31·8%. In the present state of the metallurgy of aluminium, only those deposits or parts of deposits which are fairly free from impurities, especially silica, can be profitably employed.

---

* " Mineral Industry," 1892-1915.

Bauxite is a highly refractory substance fusing at 1820°C. Moreover, when fused it crystallizes and becomes identical in composition and physical properties with corundum. It is, therefore, in great demand, not only as aluminium ore, but also as a refractory and as an abrasive, the latter being sold under the name of alundum. The demand for high grade bauxite is consequently very considerable, and although at the present time the known supplies are more than equal to this demand, sooner or later the necessity will arise for additional supplies, or for other sources of aluminium. Already active prospecting for bauxite is taking place in countries where its importance is fully realized.

Before the discovery of bauxite, cryolite ($3NaF.AlF_3$), a remarkable mineral only known in quantity at Ivigtut in Greenland, was the chief source of aluminium. It is still indispensable in the electro-metallurgical process by which aluminium is now made, the fluid vehicle in which the bauxite is dissolved and electrolysed consisting of a fused mixture of cryolite and fluorspar. The cryolite itself is not decomposed, but a certain wastage occurs which has to be made good, and for this purpose a constant supply of the mineral has to be maintained.

British production of Bauxite.—The only deposits of bauxite which are at present known and worked in the British Empire are those of County Antrim, Ireland. They occur as variable beds or seams lying between the older and newer sheets of Tertiary basalt, and seem to have been formed by the weathering, under tropical conditions, of the surface of the earlier basalt during the interval which elapsed between the first and second eruptions. The later basalt sealed up and protected the irregular mantle of bauxite which had been formed, and which has since been partially exposed by denudation, and become accessible.

The seams are very irregular, and are often sufficiently ferruginous to be used as an iron ore, especially in conjunction with the Cumberland red hematites, the alumina content being valuable for slag-making purposes. The purer material is treated at works near Larne, and the extracted alumina is sent to the hydro-electric installations in Scotland for electrolytic recovery of the metal. The total output of bauxite does not greatly exceed 5,000 tons a year, equivalent to some 1,500 tons of metal.

Extensive deposits of laterite occur in India, British Guiana and other British possessions in the tropics. Some of these are essentially bauxite, but being impure and of low grade they have as yet yielded little or no commercial ore. It is believed, however, that they may possibly form the basis of a large aluminium industry in the future. They will be referred to again under potential as distinguished from actual sources of the metal.

Foreign production of Bauxite and Cryolite.—The principal centres of bauxite production abroad are in France and the United States. That raised in the States, with the exception of a small proportion smelted in Canada, is retained for domestic production ; of the French considerably less than one-half is retained, the rest being exported to England, Germany, and other European countries, and to the United States and Canada.

The French deposits are as yet the most productive in the world. They are situated in the extreme south-east of the country, and were first located near Les Baux to the north-west of Marseilles. The soft clay-like ore is worked mainly at the surface, but to a small extent underground. As usual it is extremely variable both along and perpendicular to the bedding. The best horizons yield some of the finest mineral known. The output from the French quarries and mines may be estimated at about 250,000 metric tons a year, and of this about 150,000 tons is exported.

Bauxite has been worked to the extent of some 5,000 tons a year in Italy. Deposits have also been discovered in Germany, Austria, and Hungary, but none of these countries has yet become a considerable producer.

In the United States the chief producing areas lie in Alabama, Arkansas, Georgia, and Tennessee. The most important are in Arkansas, where the bauxite occurs as a superficial mantle produced by the weathering of igneous rocks—nepheline syenites—characterised by a high content in alumina and alkalies. During 1912 the American output was about 160,000 metric tons, of which the Arkansas deposits furnished nearly 130,000. But since that time the production has greatly increased, and is now not far short of the French.

All the cryolite used in the production of aluminium is obtained from south-western Greenland. The greater part is shipped to Copenhagen, but some goes direct to the United States. These are the two centres of distribution. The consumption of the mineral may be taken as about 10,000 metric tons a year, but is steadily increasing. As the cryolite vein at Ivigtut has been worked for many years, and cannot be inexhaustible, an interesting problem for aluminium metallurgists presents itself as to what mineral or what substitute could be used, or would be available for the same purpose were the supply of this key-mineral for any reason to be no longer forthcoming.

World's Production of Bauxite and Aluminium.—The following figures taken from the Colonial and Foreign Statistics in the Mines and Quarries General Report issued by the Home Office show the world's production of bauxite for 1912.

WORLD'S PRODUCTION OF BAUXITE FOR 1912.
(Metric Tons.)

France	258,929
United States	162,432
Italy...	6,716
British Isles	5,883
India	965
	434,925

This total serves not only for the production of the world's supply of aluminium, but also for the manufacture of bauxite bricks, alundum, and of various useful aluminium salts.

The figures indicate that of the bauxite raised during that year the British Empire contributed only about 1·57%, while France and the United States contributed 59·5% and 37% respectively. Since that time, however, the French and American outputs have considerably increased, while the British has not, so that the proportion of British origin is now still smaller. The dependence upon ore raised in foreign countries is greater in the case of aluminium than of any other of the industrial metals.

The following estimate of the production of aluminium metal for 1912 is taken from the statistics of Henry R. Merton & Co., Ltd. :—

WORLD'S PRODUCTION OF ALUMINIUM IN 1912
(Metric Tons.)

United States	19,500
France	13,000
Germany Austria Switzerland	12,000
Canada	8,300
British Isles	7,500
Norway	1,500
Italy	800
	62,600

The proportion of metal produced within the Empire according to these figures is a little more than 20% of the world's production. This more favourable figure is due to the fact that besides smelting our own domestic bauxite, we also smelt foreign material imported into the British Isles and Canada. Before the war the metal produced in Canada was exported to the United States, but it has now been commandeered by the British Government for use in England,* so that the whole of the 15,800 tons produced in the Empire is available for Inperial requirements. For so much of this as is obtained from imported bauxite, however, we are dependent upon foreign supplies. British consumption in 1912 is given as 4,000 tons, but at present it is doubtless much greater.

For cryolite the Empire is dependent upon Denmark and the United States which control the distribution of the Ivigtut material.

Other possible sources of Aluminium.—The minerals which play a part in present day production of aluminium have now been indicated. The known supplies are sufficient for existing needs, but are entirely inadequate for the needs of the future. In view of the increase in the consumption of bauxite, which has characterized the last few years, and the practical certainty of a greatly accelerated increase in the near future, the discovery, either of other deposits of bauxite, or of other commercial sources of aluminium will shortly become a matter of serious urgency.

To the British people it has already become an urgent matter because the known resources of aluminium ore within the Empire constitute such an insignificant proportion of those of the rest of the world. An enquiry as to whether adequate supplies of the ore now used, or of other materials offering promise of large future aluminium resources occur in the Empire, is of the first importance if it is desired to attain to a position of security and independence in the matter of this coming metal.

With regard to other supplies of the ore now used, sufficiently systematic search by prospectors competent to recognise it does not seem to have yet been made. Bauxite is a material not easy to distinguish, without chemical examination, from common clay, and is liable, therefore, to be overlooked by the ordinary prospector. Those in charge of geological surveys and mining departments of our colonies should direct particular attention to the systematic search for bauxite, and all clays and clay-like substances should be subjected to such tests as permit of the distinction between it and ordinary clay. Residual clays overlying igneous rocks or felspathic metamorphic rocks, and in particular those occurring in tropical latitudes, should be carefully examined.

---

* *Engineering and Mining Journal*, January 8th, 1916.

Of materials, other than bauxite, which may be regarded as potential sources of aluminium, and concerning which, therefore, the resources of the Empire should be ascertained, the most important, are corundum, alunite, potash felspar, laterite, and clay.

Corundum.—This is an oxide of aluminium containing 52·9% of the metal, and, if found in quantity, would constitute a high grade aluminium ore. But judging by known occurrences it does not seem likely to be discovered on a large scale. The present supplies are wholly absorbed for abrasive purposes, and command a higher price than bauxite.

Alunite.—The shortage of potash during the war, owing to the non-availability of the German supplies, has led to the search for other sources of potash salts. Among the minerals which have suggested themselves is alunite ($K_2O.3Al_2O_3.4SO_3.6H_2O$) The special interest of this mineral in the present connection is that it might serve as a source not only of potash, but also of sulphuric acid and of alumina. On ignition it loses all its water and three-quarters of its sulphuric acid. By leaching the residue with water, potassium sulphate may be dissolved out, and recovered by evaporation. The remainder consists of aluminium oxide. Of pure ignited alunite 32·7% consists of available sulphate of potash, and 67·3% of nearly pure alumina. The residual alumina might be used as an additional source of aluminium metal.

The mineral, at one time thought to be rare, is already known to occur in quantity at a number of widely separated localities. It is found in trachytic lavas, in which it has been formed by the action of sulphurous emanations upon the potash felspar. Regions in which this type of rock occurs on a large scale should be carefully prospected. It seems not unlikely that the mineral might be found in many of them.

The largest deposit of alunite known occurs and is worked at Bulladelah in New South Wales. The mineral has also been found in South Australia and Victoria, in India, and on Vancouver Island, Canada.

It has long been worked for the manufacture of alum in Italy, near Rome. In the United States considerable attention has recently been given to it, and important resources have been discovered in Utah, Colorado, and Nevada. The ignited mineral is believed to be now used in America and to be imported to Europe as a potash fertiliser.

In considering possible sources of aluminium ore this mineral must be borne in mind. As found in bulk it is often very impure, but processes for the separation of the alumina from the associated impurities, both in alunite and in impure bauxites, and of concentrating it in a form suitable for aluminium production, have been much studied. This is not the place to consider these in detail. It must suffice to mention one of them as an example—the Serpek process—by which the alumina in the crude mineral or residue is converted into gaseous aluminium nitride, and withdrawn from the impurities, which remain behind unaffected. The gas in contact with water is decomposed with the production of alumina and ammonia, and if the water be acidified, the latter may be recovered as an ammonium salt for fertilising purposes, while the alumina is available for metallic aluminium.

Felspar.—Bauxite and alunite are practically certain not to be found in quantities which would permit of the continued production of aluminium on a large scale. Such new deposits as may be discovered will merely serve as temporary sources. Sooner or later, if the metal is to be employed on the grand scale, the ubiquitous silicates will have to be utilized as the permanent sources. The production of aluminium from these has been the subject of much investigation, and there seems little doubt that it will eventually become possible on a commercial scale. The two principal silicates suggested are potash felspar, and clay. A point favouring felspar is that in the process of breaking down it might be made to yield potash for agricultural purposes as well as alumina. The elaboration of a commercial process yielding these products would benefit two widely different industries, and would go far to remove the monopoly of potash salts now enjoyed by Germany, and, by rendering available a plentiful supply of this most important of all fertilisers, might do much to increase the agricultural output of the Empire.

Laterite and Clay.—It is well known that in many tropical regions there exists in great quantities a disintegration product, usually more or less ferruginous and impure, which forms a discontinuous blanket over the outcrops of certain types of rock, and which has originated by a special process of chemical decomposition. This material, termed laterite, was originally thought to be a ferruginous residual clay, but is now known to differ from clay in being more or less completely desilicified. It is, in fact, an impure and partly made bauxite. It has been reported in large quantities in India, the Malay States, West Africa, Guiana, and other British possessions in the tropics, and has even been worked to a slight extent, as bauxite, in some of them. Most laterite is too crude and impure, and yields too low a proportion of alumina to compete with the bauxites now worked. But if and when the demand for aluminium becomes greater and extraction processes cheaper, this low grade material may possibly become, as the purer bauxites are exhausted, a great aluminium reserve. One of the most necessary investigations with regard to the aluminium industry is that of the location, analysis, estimation of quantities, and possible utilization of this material. In connection with this an enquiry is also necessary as to suitably placed supplies of water power, in view of the fact that laterites will not bear the charges of long distance transport, and that aluminium extraction by coal power is not profitably possible. India would seem to possess, in the Central Provinces, fine resources of laterite, and has also possibilities of hydro-electric installations on a large scale.

Laterites vary through lateritic or bauxitic clays to ordinary clays. As soon as a process for the recovery of alumina from clay is put upon a commercial footing these low grade mixtures of clay and bauxite will become available. Such materials would naturally be made use of before clays themselves were called upon. Of the processes for the recovery of the metal from clay a large number have been patented within the last few years. It is believed by many that the problem has already been solved, and that the practical adoption of one or more of these processes is only a matter of time. If this is indeed the case it is high time that the systematic examination of clays, whether residual or sedimentary, in all parts of the Empire was seriously undertaken.

Conclusion.

Summarising the evidence of the foregoing pages it would seem that, with regard to four out of the five metals dealt with, the Imperial position is wanting in independence and security.

In the case of lead and zinc, more especially the latter, this is due not to any dearth of domestic ores, but to a lack of smelting enterprise. In that of copper it is due both to a deficiency of ore production—which is possibly insuperable owing to an inadequacy of copper ore resources—and to the export of British ores or crude products for metal recovery in foreign countries. In the case of aluminium it is due to an insufficiency of the high grade ore which alone is at present employed, and not to the absence of smelting facilities, foreign ore being imported for treatment both in Great Britain and Canada. In the case of tin only is our position really strong, and even here, in order to consolidate it and keep it impregnable, improvements in ore-winning and metal extraction, seem to be imperative.

From the consideration of the resources of these metals a number of principles affecting the conservation and development of Imperial mineral resources generally, have suggested themselves, and it is proposed in the concluding paragraphs to refer to these.

In order to improve the Imperial position as to mineral supplies two courses may be adopted—to utilize more adequately known deposits, and to discover or acquire fresh ones.

Fuller utilization of known deposits.—In the first place all wasteful methods involved in the incomplete removal of ore from the deposit—as in the working of rich parts only of tin alluvials by small scale methods, when large scale operations would render poorer ground also available—the imperfect recovery of mineral from ore—as in much of the present day tin dressing with losses up to 40%—or the partial recovery of metal from mineral—as in current zinc extraction with smelting losses of from 10 to 20%—should, as far as possible, be eliminated.

A matter of importance as facilitating the exploitation of low grade deposits is the recovery of by-products. Ores must be made to yield all the materials of value they contain. Formerly an ore was mined exclusively for a particular metal. That metal extracted, the residues were waste products. Wolfram was once a waste product from tin ores, and blende from silver-lead ores. Great improvements in this matter have taken place, and a careful distinction is now made between waste products and by-products. It is recognised that by-products may determine the exploitability or otherwise of a given deposit. Many low grade copper deposits could not be profitably worked for copper alone, but the recovery of small quantities of gold and silver permits of their exploitation and thus leads to the utilization of a copper deposit which would otherwise lie untouched. From the Sudbury ore not only nickel and copper are extracted as the main products, but also gold, silver, platinum, and palladium as by-products. The complex lead-zinc ores of British Columbia are made to yield besides lead and zinc, in favourable cases, copper gold and silver also. Every prospective ore should be subjected to careful scientific investigation to determine its full possibilities. If it contains materials hitherto unmarketable because of lack of industrial applications, *e.g.*, tellurium from gold tellurides, and titanium from titaniferous iron ores, research should be undertaken to discover uses for these. The value of such investigations has often been exemplified. The utilization of tungsten ores was not possible until a demand had been created by the discovery of the value of the metal for high-speed steel and electric lighting. The tin ores of Bolivia are marketable with some difficulty because of their impurities. It is possible that by the electrolytic refining of tin these very impurities might become additional sources of profit.

In order to avail ourselves of the low grade deposits, which have such a wide distribution but which have largely awaited development, it will be necessary to organise and introduce large scale operations of high engineering efficiency, which make use of capital and power in the most economical and advantageous way. The combination of operations of this kind with the recovery of by-products, by reducing working costs and increasing revenue, brings within the scope of profitable mining, deposits which would otherwise remain undeveloped. "The net result of this type of exploitation is to increase rather than to decrease the Nation's resources."*

Here may be mentioned the desirability of the fuller use of water power for smelting, and where possible for mining and milling. The Empire possesses, in Canada, Africa, India, and elsewhere, some of the finest inland sources of water power known. Canada with great mineral wealth and power-supplies might conceivably become one of the leading smelting centres of the world, not only dealing with its own ores—which it now largely exports to the United States—but with imported ores from North and South America, China, Australia, etc. In the British Isles we possess the finest coast in the world for tidal power which only waits to be harnessed.

Another matter which calls for serious consideration is the wide-spread manner in which either raw ores or partially smelted materials, produced within the Empire, are exported to foreign countries for the recovery of the finished products. The export to the United States of the copper ores of Quebec, of the copper and zinc ores of British Columbia, and of the copper-nickel mattes from Sudbury may be cited as examples; so also may the shipping, to Germany and Belgium, of the greater part of the zinc concentrates from Broken Hill. The effect of this export of raw materials is two-fold. In the first place, the benefit in wages, skilled employment and greater profits, involved in the working up of a refined metal from its raw materials is lost to the British community; and in the second, control of the finished metal, and of the art of producing it, passes into alien hands. In this way supplies of indispensable metals and other materials can only be obtained by paying enhanced prices, or might be, and indeed have been, cut off altogether in times of urgent need. Import rather than export of raw materials should be encouraged. And the establishment of industries making for economic independence as regards essential products should be promoted.

Other nations have not been slow to realize the advantage of this acquisition of raw materials from outside sources, as is shown by the following passage written by the Director of the United States Geological Survey: "The labour of any country is most benefited by the export of finished products rather than of crude ores, and by the import of raw materials rather than of manufactures. Looking at the question from the standpoint of the United States, it is the product of American labour, rather than the bounty of our national resources that should go into the world's markets, for betterment of industrial conditions can come best through expansion of manufacturing. The increase in the element of labour in the product exported will mean that we are not bartering away our heritage of national resources, but rather that we are using those resources as a basis simply for the expenditure of labour, which renews itself."*

---

*Otis Smith: "The Public Interest in Mineral Resources." (U.S. Geol. Surv., 1915.)

Various methods of preventing the undue exportation of raw materials have been attempted. These are principally of two kinds—discouragement of the alien purchaser by a prohibitive tax upon exported ore, and encouragement of the inside smelter by bounties upon finished metals produced within the Empire from domestic ores. The former was applied with success a few years ago by the imposition of a tax upon tin ore exported from the Malay States, at a time when an attempt was made to ship it, at ballast rates, for smelting in the United States. The latter has been successfully adopted by the Government of Canada in connection with the lead-ores of British Columbia, which were formerly exported to the United States. Within a few years of the granting of these bounties the export ceased and all the ore is now smelted and refined within the Dominion at Trail. More recently bounties have been granted upon copper and zinc produced in the Dominion from domestic ores. The effect of these will be watched with interest. Opinions differ as to the economic soundness of such methods, but in any case the matter is one that calls for consideration and action.

The full output from some of the remote mineral fields of the Empire is seriously hampered by difficult and costly transport. The effect of this in hindering or entirely preventing development has already been referred to in the cases of Australia, Nigeria, and Canada. More vigorous Government action in well established and suitable cases might be taken and greater production be thereby promoted.

The discovery or acquisition of fresh deposits.—The first requisite is precise information as to what the mineral resources of the Empire really are. This to a large extent already exists in the publications of the various geological surveys and mining departments, but not in a convenient or easily accessible form. Existing information needs to be collected, co-ordinated, standardized, and summarized, and much new information to be obtained and recorded.

Geological and mineral surveys of all British Territory should be expedited. New surveys would need to be instituted and the staff of existing ones to be augmented. With the small staff of most of our surveys the completion even of a preliminary reconnaisance of any real value, within a reasonable time, to say nothing of an adequate geological investigation, is quite impossible. Moreover such surveys should include a proportion of men specially trained in the economic as well as the purely scientific side of geology—men with not only a sound knowledge of economic geology and mineralogy, but with a useful general acquaintance also with the theory and practice of mining and metallurgy. If the supply of such men is insufficient, it should be increased by the support of institutions where such training is available, and by the encouragement and assistance of promising students. The paramount importance, in the development of mineral industries, of men of this stamp has been realised in the United States where the mining geologist is probably more efficient and of more value to the State than in any other country in the world. The services of such men should be used not only in prospecting for new deposits, but also in the development of mining fields.

---

* Otis Smith : *Loc. cit.*

It must be remembered also that the prospecting of to-day is not that of ten or twenty years ago. It is no longer a primitive craft based upon limited experience and vague knowledge but an art founded upon scientific training and wide experience. The prospector should now possess, besides a thorough knowledge of geological processes, materials, and structures, a precise acquaintance with all minerals of actual or potential commercial value, and a familiarity with the broad principles underlying the exploitation of mineral resources both on a large and on a small scale. In this connection a plea is put forward for the more general adoption in the British Empire of special methods of prospecting for or exploring mineral deposits, such as diamond drilling and the magnetic survey. The former method offers great possibilities, especially when applied to the location of new orebodies in districts in which the mode of occurrence and origin of the deposits and the general geology are already well known. Its employment in connection with water, oil, and coal is fairly universal, but has not been sufficiently attempted in regard to ore deposits. The desirability of applying the method to the discovery of blind tin lodes in Cornwall has already been referred to.

In order to hold our own with scientific and technological progress in such countries as Germany and the United States, advance investigations should be carried on continuously with the object of improving current processes, or introducing new ones by which abundant materials, which have hitherto proved refractory or unprofitable, may be made productive. As illustrations of investigations promising great rewards in the future may be mentioned, the utilization of felspar as a source of potash and aluminium, the extraction of aluminium from clay, and the recovery of lead, zinc, copper, silver, and gold from complex sulphide ores by continuous electro-thermic and electrolytic methods. These are selected from among many others which suggest themselves. They are being seriously worked at in America and Germany. It is doubtful how far either of them is being studied in the British Empire. Investigations such as these are of national importance, and should receive national support. They are imperative if we are to compete successfully with other countries in the mineral industries.

The development of the mineral resources and industries of the Empire seems to have taken place in the past without any constructive Imperial policy. It has lacked co-ordination and control, and is urgently in need of enlightened, broad-minded, and business-like administration. The events of the last two years have made this startlingly clear ; and probably the most valuable suggestion towards rectification, which has recently been made, is that addressed to the Advisory Council for Scientific and Industrial Research, by the Councils of four of our largest mining and metallurgical institutions, that a special Government Department should be established to foster and safeguard mineral resources and promote the welfare of related industries. Mineral statistics need to be collected and published, information to be gathered and distributed, investigations to be organised and carried out, methods of encouraging and protecting young industries to be adopted, laws and customs affecting mining to be modified. These and many other functions such a body could perform, and it is much to be hoped that the efforts of the signatories to the memorandum will be successful, and that a Department of Minerals and Metals will come into existence. There can be little doubt that some such controlling department is needed, and that, if formed and properly conducted, it would do much to give security and order to what is now full of danger and disorder.

DISCUSSION.

The President (Mr. Percy Griffith), said that the Society had so much valuable material before it on this occasion that it was difficult to deal with it adequately in one afternoon and evening. He was sure that the meeting would cordially support the vote of thanks which he had the pleasure to propose before the discussion was opened. He had an interesting announcement to make which, by rights, should have been deferred until the Annual General Meeting to be held presently, but he was sure that all those present would be glad to hear that the Council had awarded to Dr. Cullis the President's Gold

Medal for his splendid paper. While the intrinsic value of this award might not be very great he felt proud to be the President in whose name this award was made, and he cordially invited both the authors to attend the meeting on the first Monday in February when the awards would be formally presented to them.

The vote of thanks was carried by acclamation.

Prof. Carpenter said he was sure that all would feel that Dr. Cullis had been eminently successful in his treatment of an important and enormous subject. The paper and the way in which it had been presented had been lucid, stimulating, scientific and practical. He did not think that higher praise could be given than that. With regard to the five metals with which the paper dealt, the position of copper was one of the least satisfactory. Part of the irony of the situation was that at the end of the eighteenth century Great Britain produced 75 per cent. of the world's copper. The raw material came from the Cornish mines, the bulk of the ore was smelted at Swansea, and so strong was the position of the copper smelters that in the first half of the nineteenth century an association was formed called the Associated Copper Smelters of Swansea, which controlled the price of the metal. Then came the opening of the great Chili copper ore fields, and, Swansea, being the world's centre of production, the cargoes went there. As this was in the days of sailing ships, the dates of arrival of the ships could not be controlled with any degree of accuracy. A number of cargoes often arrived about the same time, which was fortunate for the smelters, because the owners of the cargoes had to compete with each other, and the selling price went down. Then came the opening up of the Great American deposits, first of all at Lake Superior, then at Batte, and later at Arizona, and America was now the greatest producer of the metal. The situation which obtained to-day was, to some extent inevitable. America, by virtue of her natural resources, was destined to be the greatest producer of copper, but he wished to point out that the Swansea smelters had accelerated the change, and he might illustrate that by a story which was told to him by the man who was responsible for it. Rather less than three years ago he (the speaker) was in America making a study of the practice of some of the big copper works. The man whom he had just mentioned told him that he had invented a roasting furnace suitable for copper ores which, he considered, was superior to anything that was being used in Swansea, and, as Swansea was the centre of production, he had sent his traveller there. The traveller called on one of the leading firms, and put the plan of the furnace before the principals. They listened to him, and then said, " How long have you been getting out this furnace ? " The traveller said, " Two years," to which they replied, " We have been smelting copper for two hundred years, and we don't think that you can teach us anything. You had better go back to America." The traveller went back, the furnace was put up and worked in America, and that was really the start of the copper smelting industry in that country. The British Empire was able to stand that sort of thing at that date, but he ventured to say that if there was any more of it the Empire might as well put up its shutters.

Dr. Cullis had raised the very important point that copper in its penultimate stages of production was largely treated in the United States, and particularly in or near New York. An American had told him that the great refineries within twenty miles of New York Harbour dealt with 90 per cent. of the world's production of copper. Allowing for a slight exaggeration, which American speakers were occasionally betrayed into, there was no doubt that that figure represented the case sufficiently nearly. There was no reason why such a state of things should continue so far as Canada was concerned. The Canadian Government was fully alive to the situation, as the author had pointed out. They had put a bounty on metal produced in the country from native ores. The Nickel Commission, of which Mr. Holloway was the chairman, was dealing with the nickel situation, which was even more dangerous, because nickel was an absolutely indispensable constituent of armour-piercing shells and of armour plates. Whereas Sudbury produced about 72% of the world's nickel, very little of it in its ultimate stage of production was under British control; in fact, only that part which went to the Mond nickel works at Swansea. He hoped they would see that state of affairs remedied in the future by the establishment of refineries in Canada.

With regard to the smelting of copper ores, the practice in America was highly specialised. Copper ores were the source not only of copper, but of gold, silver, platinum, and pallatium, and he (the speaker) had found tellanium and selenium as well. Considerable quantities of these latter two elements were produced, and the Americans were busy finding out uses for them. There was no doubt that the American practice in copper metallurgy was exceedingly good.

With regard to zinc, he considered that, given proper management, there was a likelihood of the development of a big zinc smelting industry in this country. In Australia, with a population of between five and six millions, there was a production of 500,000 tons of ore, representing potentially about 200,000 tons of metal. The Broken Hill Concentrates were sources not only of zinc, but of sulphuric acid, lead and silver. He entirely agreed with the author that minerals ought to be worked up for every product which they contained and which could be used. If they considered that the working up of the 500,000 tons in Australia would involve the production of far more acid than could be absorbed in that country, there seemed to him to be a very strong presumption in favour of the export of the ore concentrates to this country, with its population of between 45 and 50 millions, and industries which could absorb the acid. The Swansea district particularly was a really splendid centre for dealing with the ore. He did not think that it was necessary for the acid to be produced at the same place as the metal. He did not wish to be dogmatic on the point, but merely wished to indicate the opinion that it might be found to be more suitable to roast the ore for acid, say, near Liverpool, which was close to the chemical industries in Lancashire, and treat the residue for allied metals at Swansea.

With regard to tin, although the ore had been worked in Cornish mines for about 2,000 years, the losses on dressing were variously estimated at between 25% and 40%. That was not very creditable, and there was room for considerable improvement. It was a source of satisfaction that the research undertaken by the Institution of Mining and Metallurgy under the auspices of the Privy Council was dealing with the important question of diminishing these losses and of extracting not only the maximum quantity of tin but also of tungsten.

Mr. W. H. Trewartha-James said, that when he heard that Professor Cullis had taken the subject in hand he felt certain it would be dealt with in a very thorough and able manner.

He agreed with the author that there was an urgent need for Government action in the matter of the utilization and conservation of the great mineral and metallic resources of the Empire. He had had something to do with the development of two or three important metal producing industries, especially gold, silver and copper. A good deal had been said about Canada's ability to produce copper, and he was quite certain that if her resources were properly administered, Canada could supply part, at least, of the Copper deficiency to which attention had been called.

In 1908 he called the attention of the Provincial Legislature of British Columbia to the necessity for erecting a refinery on Vancouver Island. At that time he was smelting the output of the famous Britannia Mines of Howe Sound, which now had one of the largest outputs on the Alaskan Pacific Coast. Enormous sums had since been spent by the Guggenheims in erecting a copper refinery, and in improving and extending their copper smelting works at Tacoma, Washington, U.S.A., with the result that this industry had passed almost entirely under American control. If the British Government now wished to recover their position with regard to the copper resources of the Pacific coast, they would have to do so at a very serious disadvantage indeed ; but with the aid of wise legislation, a subsidy on refined or manufactured copper, and, perhaps, a small export tax on local ore going into America, for which he had begged a few years ago, a great deal might still be accomplished. He had travelled from the copper fields of Whitehorse, Alaska, down to the Southern parts of Mexico, and as far as Antofagasta, in search of copper ores, and he thought that a refinery established at Vancouver Island would be one of the greatest factors in supplementing the copper deficiency to which Professor Cullis had called attention, and would help to keep the production in our own hands.

The Britannia Mines of British Columbia sent all their ore to Tacoma, and it was all being smelted, converted and refined there. For want of Government support a large British smelter on Vancouver Island with a capacity of about 1,000 tons a day, had been allowed to drop out of the fight for the last five years. There was no need for the Empire to be short of copper. The ores occurred in enormous quantities, not only throughout the Empire, but in places where British capital predominated.

When America started to flood the world with "eleven cent" copper, many British and Colonial mines could not keep open without Government help. They closed down, and remained closed, although electrolytic copper to-day fetched thirty-three cents. per pound. He was sure that a proper investigation of the resources of the Empire, and of those parts of the world where British capital had free scope, would help to put the British Empire back into the place, which, in regard to copper. it occupied in 1875. What was being done about the copper resources of Ireland, of Wales, and of other parts of the United Kingdom—nothing at all !

With regard to tin, he had no doubt that the research so wisely inaugurated by the Research Advisory Council of the Government, would be of great value to the tin mining industry of Devon and Cornwall. Professor Cullis had shown how America for the second time was making a fight to get a tin smelting position. They knew that the Harney Peak deposits were of very little use for permanent operations.

By the exploitation of tin deposits in Yorke Peninsula, N.W. Alaska—in a bitterly cold and difficult region—America might develop a small tin smelting position of her own, but so far as the new departure of smelting Bolivian tin concentrate was concerned, he thought the Americans would probably fail a second time. Professor Cullis had told them how legislation in the Malay States had stopped America from getting hold of the tin smelting industry there, and the same thing would happen again if Bolivia placed an export duty on itn-ore concentrate, etc., and gave a local subsidy or bounty to the people intelligent enough to look ahead and to erect local smelting works. Would these be Germans, or British or Americans, that was the real question.

Professor Cullis had pointed out that Australian zinc and lead ores might be smelted at Trail, B.C. That was largely a question of overland freight rates. The ocean rates could probably be brought down low enough. He had transported copper ore on the Pacific coast a thousand miles at a rate of $1·25c. (5s. 3d.) per ton, and copper ore from Japan and from China was sent across the Pacific Ocean to coast smelters at ballast rates. It would not be reasonable, however, to expect that ores could be brought across the seas, and then sent by a long railway journey to Trail to compete with coast smelters. The coast, Prince Rupert's Island and Vancouver, with their cheap ocean transport, and cheap coking coals, water power, etc., were the best points at which the whole of the Western Pacific trade might be caught.

With regard to zinc smelting, Australia was now playing its own hand, and a very important hand, too, in that matter. It was true that Australia could produce ample zinc and lead concentrate for smelters in this country, and still supply other Colonial smelters, but he believed that in the near future Australia would take care of her own smelting. A powerful Smelting Company, supported by the Australian Government, had been founded to smelt zinc and lead ore in Australia, and was now dealing with the question.

In conclusion, he desired to express his agreement with Professor Cullis's plea for immediate Government action. It could not be too strongly urged ; his only difficulty was to find language strong enough to indicate the great urgency of the matter.

Dr. Elsden said that it had given him great pleasure to hear the excellent papers. The papers contained an enormous number of useful suggestions and problems for scientific research. He thought that one of their great values was that they would serve as a means for students to estimate the problems that required solution. The papers threw a great deal of light upon questions which had been neglected, probably, to a large extent, through ignorance of the fact that they even existed. He congratulated the authors upon the results of their labours.

Professor Fearnsides said, that the author in considering the question of tonnages for the five metals he had dealt with had said that they came next after iron in importance. He did not mention steel. If the author would go into the question of the tonnage of the world's consumption of manganese ore required for making steel he would find that in weight of ore produced manganese ranked next after copper and that for weight of metal contained in the ores produced (most manganese ores carry 30-50 per cent. of manganese) manganese must be advanced to second place.

Professor Cullis had drawn attention to what he regarded as a very unsatisfactory condition of things in this country with regard to ores of aluminium. No doubt the author recognised that far more important than the price of the bauxite in determining the cost of metallic aluminium and becoming of surpassing importance if the aluminium was to be obtained from low grade ores, was the cost of the electric power required to reduce it. Each ton of iron made represented the energy got from over two tons of coal, but each ton of aluminium manufactured by present day processes represents all the power which modern engines can develop from the consumption of over six tons of coal. The manufacture of aluminium, therefore, is only economically possible on a commercial scale where cheap and abundant water-power is available.

On Prof. Cullis's world-map showing actual and potential supplies of bauxite the speaker had noted a square at about the place of British Guiana. He could assure the author that along the Essiquibo river in that colony there is a great spread of aluminous laterite of first-rate quality which an American syndicate has already begun to exploit for bauxite, and which later by the harnessing of the waterfalls of the hill country adjoining, may make British Guiana a country quite important for supplying the world with aluminium.

He wished his congratulations to be added to those which previous speakers had already offered to the author.

Reply.

Prof. C. Gilbert Cullis thanked the gentlemen who had taken part in the discussion. He apologised for having taken so long in presenting his case, but he had had to deal with so many important materials that treatment of them all, even in the time taken, had been very difficult.

With regard to Prof. Fearnside's claim for manganese, what he (the author) had said was that aluminium ranked in importance after iron, copper, lead, zinc and tin. He had meant as metal for construction purposes, and maintained that the statement was correct. Manganese was not used directly in the metallic condition as the other metals named were.

He was interested to hear what had been said about additional supplies of bauxite. He knew that supplies had been reported in British Guiana. Of the tropical portions of British territory there occurred deposits of laterite which called for careful investigation. It was quite likely that here and there, as in India and British Guiana, some of these might be sufficiently pure for immediate utilization. In British Guiana, for example, the laterite was said to be fairly free from impurities and appeared to be a high grade bauxite.

He expressed his very sincere thanks to the President and Council for the award of the President's Gold Medal, and said how very highly he appreciated the honour which had been conferred upon him.

Mr. J. Allen Howe of the Geological Museum, Jermyn Street, S.W.. wrote :—

" Professor Cullis has given an excellent bird's-eye view of the great diversity of mineral substances which are of economie importance and of the main facts of their distribution. There are many points one would like to discuss, some of them of technological interest, others involving broad questions of policy, but I will content myself with a brief reference to one or two questions raised in his concluding remarks. With regard to the " utilization of known deposits " and the importance of the by-products of their manufacture, this may be fairly left in the main to commercial concerns whose obvious duty to themselves is to do the best they can in this direction, indeed the best of them are always keenly alive to sieze every opportunity for improvement. But much remains to be done in the direction of carefully organised " advance investigations." If we are to obtain the fullest value from such investigations and avoid disconnected and often unfinished efforts, there must be some permanent authoritative body representing the best opinion available among technologists, scientists, etc., to advise as to the investigations to be undertaken, to secure continuity and keep the investigators in touch with one another and with the interested industries. The work, in detail, could be carried out in the universities and mining schools of different parts of the empire, but general control over the work and over the publication of results should be in the hands of the advisory body. A great step has been taken in this direction by the formation of the Committee of the Privy Council for Scientific and Industrial Research, but it is a subject which should continually be before the councils of Institutions interested in the metal and mining industries, advice and guidance should proceed from these bodies, the central control.

" With respect to the second sub-head, " Discovery or Acquisition of Fresh Deposits," it is true that the first requisite is precise information as to what the Empire resources really are. There can be no question as to the desirability of expediting not only the preliminary surveys of all unknown tracts in every part of the empire but also as to the need for hastening on the detailed examination of all areas which show promise of economic importance. Experience proves most emphatically that the details of economic geological information gathered in the course of such surveys cannot be too complete.

"I would endorse in the strongest manner what Prof. Cullis says of the need for co-ordination, standardisation and summarization of the information on mineral occurrences. This must be done by a central organization with properly equipped staff if it is to be done promptly, satisfactorily, and economically. A great amount of energy and money is at present wasted by separate organisations, both public and private, each doing a little towards this end and overlapping in the process. It is essential that such an organisation should be in the closest possible touch with those branches of industry which depend directly or indirectly upon mineral substances, and these, putting aside the great key industries, are far more numerous than most people imagine. Although the main business of a central organisation would lie within the Empire, it must not be overlooked that prompt information respecting foreign resources and markets is of the greatest value, but our existing service is often lacking in technical exactitude, a failing which could be remedied if an expert body were permitted to edit the data."

ANNUAL GENERAL MEETING.

The Seventh Annual General Meeting of the Society was held in the Apartments of the Geological Society, Burlington House, Piccadilly, W., on Monday, December 11th, 1916, at 7.45 p.m., the President, Mr. Percy Griffith being in the Chair.

The notice convening the meeting was read.

The Secretary read the Report of the Scrutineers on the result of the Postal Ballot for the election of the Council and Officers for the year 1917 (see page 274).

The Report of the Council for the year 1916 was taken as read.

Messrs. Begbie, Robinson & Cox, Chartered Accountants, were re-elected as the Auditors of the Society for the ensuing year.

A vote of thanks to the Scrutineers, Messrs. A. T. Walmisley and J. K. Foord, was proposed by Mr. E. H. Brewster, seconded by Mr. F. L. Ball, and carried unanimously. The meeting closed at 8.0 p.m.

REPORT OF THE COUNCIL FOR THE YEAR 1916.

In presenting their Seventh Annual Report since the Amalgamation and Incorporation of the constituent Societies, the Council have to state that the membership at this date is as follows :—

Hon. Fellows	23
Fellows	53
Members	300
Associate Members	189
Associates	27
Total	592

The Council are gratified to observe that this total shows an increase over that for last year.

There are also about 25 members of student Societies affiliated to the Society.

About 70 members are known to be on active service with the Allied Forces, and many others are engaged on important work connected with the war.

The Council have to record with deep regret the deaths of Earl Kitchener of Khartoum and Sir William Ramsay, D.Sc., F.R.S., Hon. Fellows ; Lieutenant-Colonel C. H. O'Connor (Past President of the late Society of Engineers), Lieutenant William Bell (Member), Captain Ernest C. Laughton (Member), Sergeant Ronald L. Corry (Associate Member), (the last three were killed on active service), and Adolph Gothard Christiansen (Member)

MEETINGS.

During the year, seven Ordinary Meetings, twelve meetings of the Council and forty meetings of various Committees, have been held.

VISITS.

Visits were made by members and their friends during the summer vacation, as follows :—

July 11th. To the Works of Messrs. Johnson and Phillips, Ltd., at Charlton, S.E.

September 7th. To the Works of Messrs. Dorman, Long & Co., Ltd., Nine Elms, S.W.

September 21st. To the Roehampton Military Hospital (Queen Mary's Convalescent Auxiliary Hospitals).

FINANCE.

The Balance Sheet and Income Tax and Expenditure Account for the year 1915, duly audited by Messrs. Begbie, Robinson & Cox, Chartered Accountants, were published in the issue of the Journal for April, 1916, and are now formally submitted to the members for their acceptance.

The Council consulted the members by a postal vote on the question of remitting the subscriptions of members on active service and of other members whose financial position is seriously affected by the war. The result of the voting fully justifies the Council in exercising their discretion in any particular case.

PAPERS AND PREMIUMS.

Mr. Percy Griffith, M.Inst.C.E., delivered his Presidential Address on February 7th, and dealt chiefly with the status of engineers, and also with the subjects of gas and water supply.

The thanks of the Society are cordially offered to the following authors who contributed papers at meetings or for publication in the Journal during the year :—

Mr. H. CONRADI : "Life Guards for Motor Vehicles."
Mr. REGINALD BROWN : "Sewage and its Precipitation : Facts and Fallacies from Laboratory and Practical Tests."
Mr. J. E. LISTER : "Modern Coal and Coke Handling Machinery as used in the Manufacture of Gas."
Prof. J. A. FLEMING : "Engineering and Scientific Research."
Mr. H. M. WILSON : "Concrete and Reinforced Concrete."
Mr. E. S. ANDREWS : "The Design of Continuous Beams."
Mr. C. T. A. HANSSEN : "Heating and Ventilating Private Dwelling Houses."
Prof. W. G. FEARNSIDES : "The Sources of the Minerals required by the Iron and Steel Industries of the United Kingdom."
Prof. C. G. CULLIS : "The Mineral Resources of the British Empire as regards the production of non-ferrous industrial metals."

The Council have awarded premiums to the foregoing for the papers contributed by them as indicated in the foregoing list :—

The President's Gold Medal to Prof. C. G. CULLIS, D.Sc.

The Bessemer Premium, value £5 5s., to Prof. W. C. FEARNSIDES, M.A.

The Bernays Premium, value £3 3s., to Prof. J. A. FLEMING, M.A., D.Sc., F.R.S.

The Nursey Premium, value £3 3s., to Mr. J. E. LISTER, Wh. Ex., A.M.I.C.E.

A Society Premium, value £2 2s., to Mr. E. S. ANDREWS, B.Sc

APPOINTMENTS' REGISTER.

During the year the Secretary received intimation of 20 vacant appointments. Of the candidates nominated for these by the Society, four have notified the Secretary that they have been appointed.

COUNCIL AND OFFICERS FOR 1917.

The result of the Postal Ballot for the election of Council and Hon. Officers for 1917 is as follows :—

President : HENRY C. ADAMS.

Vice-Presidents : W. B. ESSON, W. N. TWELVETREES, F. L. BALL.

Members of Council : HENRY ADAMS, CHARLES T. WALROND, G. A. BECKS, The Rt. Hon. LORD HEADLEY, BURNARD GEEN, T. J. GUERITTE, A. MARSHALL ARTER, H. T. CHAPMAN, P. F. MACKENZIE-RICHARDS, H. SHAW.

Associate Member of Council : R. L. SIMPSON.

Hon. Secretary and Hon. Treasurer : Mr. D. B. BUTLER.

The thanks of the Society are due to the Scrutineers of the Ballot Lists, Messrs. A. T. Walmisley and J. K. Foord, for their services.

PROFESSIONAL STATUS.

The Council have continued their work in connection with the professional qualifications, fees, and etiquette of consulting engineers, while various questions affecting salaried municipal engineers are being considered by a Joint Committee representing this Society, and the Institute of Municipal and County Engineers, and it is hoped that some useful action may be initiated early in the New Year.

17, VICTORIA STREET, S.W.

INDEX TO TRANSACTIONS, 1910-16.

The date following each title indicates the year of publication, and the page reference is to the volume of Transactions for that year.

PAGE.
Abattoirs (*see Slaughter*).
Accretion at Estuary Harbours on the South Coast of England. Gerald O. Case, 1913 205
Annual General Meeting, 1910 292
——— 1911 408
——— 1912 343
——— 1913 277
——— 1914 344
——— 1915 283
——— 1916 271
Balance Sheet and Accounts, 1911 114
——— 1912 31
——— 1913 65
——— 1914 56
——— 1915 46
——— 1916 96
Bridge Foundations in the East and the Sittang Railway Bridge, Burma Railways. A. S. Buckle, 1914 251
'Bus *v.* Tram Controversy. W. Yorath Lewis, 1913 20
Cartridge, Uses of the Hydraulic Mining. James Tonge, 1914 ... 285
Chimneys, The Design of Tall. Henry Adams, 1911 363
Coal-field, The South Eastern. B. L. Rigden, 1913 7
Coast Protection (See *Accretion*).
Colonies, as a field for Engineer work, (The). H. Conradi, 1911 ... 218
Concrete and Reinforced Concrete. H. M. Wilson, 1916 139
Corrosion (See *Iron*).
Council, Report of, 1910 293
——— 1911 409
——— 1912 344
——— 1913 278
——— 1914 345
——— 1915 284
——— 1916 272
Design of Continuous Beams, The. Ewart S. Andrews, 1916 ... 161
Dinner, Amalgamation, 1910 1
——— 1911 7
——— 1911 197
Drawing Office Organization. F. G. Woollard, 1911 231
Electrical transmission of power for Marine Transportation. W. P. Durtnall, 1912 267
——— Trolley vehicle system of railless traction. Henry C. Adams, 1912 35
Electricity from the Wind. A. H. Allen, 1910 ... ... 7, 19
Empire Development, Engineers and. C. R. Enock, 1910 ... 165, 177, 193
Energy from the Sun, The Utilization of. A. S. E. Ackermann, 1914 81
——— 1915 177
Engineering and Scientific Research. J. A. Fleming, 1916 ... 101
——— Troubles in Africa and their Solutions, Some. G. A. Becks, 1910 197
Engines, Two-stroke Cycle. R. W. A. Brewer, 1911 303

PAGE
ESPERANTO, An International Language for Engineers. T. J. Gueritte, 1914 59
FERRO-CONCRETE (See *Reinforced Concrete*).
GAS, Petrol Air. E. Scott-Snell, 1911 73
GAS WORKS, The re-construction of a country. A. E. Whitcher, 1915 223
HARBOURS (See *Accretion*).
HEATING and Ventilating Private Dwelling Houses. C. T. Alfred Hanssen, 1916 189
HEATING and Ventilation. A. H. Barker, 1915 115
HIGHWAYS. C. H. Cooper, 1913 171
INDIA, Irrigation in. R. H. Cunningham, 1914 205
INSPECTION OF MATERIALS (*see Testing*).
INTERMITTENCY; its effect in limiting electric traction for city and suburban passenger transport. Wm. Yorath Lewis, 1912 ... 121
IRON, Corrosion and Rusting of. Eric K. Rideal, 1913 239
IRRIGATION in India. R. H. Cunningham, 1914 205
LANGUAGE, Esperanto for Engineers. T. J. Gueritte, 1914 ... 59
LAW and Engineering, Some points of contact. S. G. Turner, 1915 195
LIFE Guards for Motor Vehicles. H. Conradi, 1916... 7
LIGHTHOUSE Design and Construction. L. S. Spiro, 1915 ... 7
LIGHTING, Electric, of steam driven trains. E. Kilburn Scott, 1914 1
LIGNO-CONCRETE. Gerald O. Case, 1912 83
LOAD, The Dynamic Increment of a uniformly distributed. Herbert Chatley, 1914 221
MACHINERY, Inspection and testing of Engineering Materials and. C. W. V. Biggs, 1910 133
MARINE TRANSPORTATION, Generation and Electrical transmission of power for. W. P. Durtnall, 1912 267
MATERIALS (*see Machinery*).
MINERAL Resources of the British Empire with regard to the Production of Non-Ferrous Industrial Metals, The. C. Gilbert Cullis, 1916 215
MINING, Uses of the Hydraulic Cartridge. James Tonge, 1914 ... 285
MODERN Coal and Coke Handling Machinery: as used in the Manufacture of Gas. J. E. Lister, 1916 65
MODULUS of Elasticity of thin flexible strips. F. H. Hummel, 1912 209
MOTOR Vehicles, Running costs of. R. W. A. Brewer, 1915... ... 51
NITROGEN Products made with the aid of Electric Power. E. Kilburn Scott, 1911 9
ORGANIZATION, Drawing Office. F. G. Woollard, 1911 231
PERMANENT WAY on Railways, The Mechanical Installation and Upkeep of. T. J. Gueritte, 1911 249
PETROL Air-Gas. E. Scott-Snell, 1911 73
POLLUTION, Subterranean erosion of water-bearing strata in relation to. Spencer Sills, 1912 7
POSSIBILITIES in Engineering. L. S. Spiro, 1913 163
POWER, Tidal Waters as a source of. C. A. Battiscombe, 1913 115
PRESIDENTIAL ADDRESSES. Diogo A. Symons, 1910 25
——— F. G. Bloyd, 1911 37
——— John Kennedy, 1912 21
——— Arthur Valon, 1913 69
——— H. C. H. Shenton, 1914 30
——— Norman Scorgie, 1915 24
——— Percy Griffiths, 1916 25
PROFESSIONAL Topics, Current. Henry C. Adams, 1910 ... 203
PUMPS, Testing Centrifugal. F. H. Hummel, 1913 149

PAGE

Rail Plateways. G. Noble Fell, 1912 199

Railless Traction, The Trolley vehicle system of. Henry C. Adams, 1912 35

Railway, The Promotion and Construction of the London and Birmingham. F. G. Bloyd, 1911 200

Railways, The Mechanical Installation and Upkeep of Permanent Way on. T. J. Gueritte, 1911 249

——— Safer, Quicker and Cheaper. C. R. Enock, 1911 ... 267

Reinforced Concrete retaining walls. E. R. Matthews, 1910 ... 181

——— Test deflections in. P. J. Waldram, 1912 311

Report of Council, 1910 293

——— 1911 409

——— 1912 344

——— 1913 278

——— 1914 345

——— 1915 284

——— 1916 272

Retaining Walls, Reinforced Concrete. E. R. Matthews, 1910 ... 181

Rivers and Waterways, National Control of. Reginald Brown, 1913 155

Roads Development Act, 1909, The Working of. Reginald Brown, 1910 265

Roads, Main; Past and Present. F. Grove, 1915 81

——— Up-to-date. R. O. Wynne-Roberts, 1910 101

Rolling, Resistance to. Herbert Chatley, 1912 179

Rusting (See *Iron*).

Sewage and its Precipitation: Facts and Fallacies from Laboratory and Practical Tests. Reginald Brown, 1916 37

Sewage Disposal Ideals. W. C. Easdale, 1910 43

Sewer from Battersea to Deptford, Construction of a L.C.C. low-level main. J. P. Harris, 1912 223

Slaughter of Animals, Mechanical Appliances for the painless. S. M. Dodington, 1914 309

Slaughter-Houses, Public. S. M. Dodington, 1910 229

Solar Energy, The Utilization of. A. S. E. Ackermann, 1914 81

——— 1915 177

Status Prize Essay. Wm. Ransom, 1913 91

Sun, Utilization of Energy from the. A. S. E. Ackermann, 1914... 81

——— 1915 177

Surveys, Reconnaissance. L. S. Spiro, 1913 145

Testing and Inspection of Engineering Materials and Machinery. C. W. V. Biggs, 1910 133

Tides, as a source of Power. C. A. Battiscombe, 1913 115

Town-planning from an Engineering standpoint. E. R. Matthews, 1912 235

Traction, Intermittency; its effect in limiting. Wm. Yorath Lewis, 1912 121

——— Trolley vehicle system of railless. Henry C. Adams, 1912... 35

Trade Unionism as applied to Professions. A. B. Howes, 1914 ... 229

Traffic Problem, The London. W. Yorath Lewis, 1913... ... 20

Trains, Electric lighting of steam-driven. E. Kilburn Scott, 1914 1

Turbines (see *Water Power*).

Vehicles, Running Cost of Motor. R. W. A. Brewer, 1915 ... 51

Ventilation and Heating. A. H. Barker, 1915 115

Water bearing strata in relation to pollution, Subterranean Erosion of. Spencer Sills, 1912 7

PAGE
WATER Conservancy, The Administrative Aspect of. W. R. Baldwin-Wiseman, 1911 120
WATER Power, The Modern Development of. A. Steiger, 1915 233
——— Supplies, Protection of. H. C. H. Shenton, 1911 157
——— Supplies, Public. Percy Griffith, 1915 157
——— Supply of Greater New York, Notes on. William T. Taylor, 1914 ... ... 167 & 241
WATERWORKS, Moulmein. P. G. Scott, 1910 79

NOTE.—A complete index to the Transactions of the old Society of Engineers will be found in the last volume published by that Society, and the volumes of Transactions of the Civil and Mechanical Engineers' Society are also indexed.

TA
1
S67
1916

~~Physical &~~
~~Applied Sci.~~
~~Serials~~

Engineering

Society of Engineers,
London
Journal

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE